GEOGRAPHIC INFORMATION SYSTEM:

PRACTICAL TRAINING MANUAL FOR AGRICULTURAL RESEARCH CENTERS

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1.1.1.1.1.1.1

Preface

Low agricultural productivity and food insecurity is of central concern in the Nile sub-basin of the Ethiopian highlands, which is commonly resulted from land degradation, poor rainwater management and low institutional capacity to facilitate adoption and dissemination of appropriate technologies and good practices.

The CGIAR Challenge Programme on Water for Food (CPWF) is an international, multi-institutional research initiative that aims to improve rainwater management in the region to improve rural livelihoods and resilience of systems. The Nile basin development challenge (NBDC) of CPWF aims to break the cycle between poverty, land degradation and low system productivity in the Nile basin by employing landscape approach to rainwater management and empowering local institutions to adapt integrated and participatory approaches and by helping farmers to move from subsistence to market-oriented agriculture and sustainable use of resources.

One of the components of NBDC, the targeting and scaling project, has been engaged in creating local institutional capacity to target and disseminate proven technologies and good practices to wider communities and systems. NBDC researchers have been working with Ethiopian regional research institutions in capacity building of staff in system analysis, to ensure that the institutes and their affiliated centers as well as other water related NGOs develop GIS skills to be able to use GIS-based targeting tools for rainwater management strategies.

This manual is the result of a very close collaboration between Amhara region agricultural research institute (ARARI) and the Nile Basin Challenge Program (NBDC). ARARI is in process of developing its own GIS center for the Amhara region to integrate GIS as an important tool for employing effective research. I hope this hands-on training manual will enable agricultural researchers improve their capacity to use GIS related tools to solve landscape level constraints affecting the rural poor in the Amhara region and beyond.

I am convinced that this training manual would fulfill the needs of agricultural researchers and their institutions in targeting technologies and up-scaling good practices from research centers to farmers' fields. On behalf of ARARI and NBDC, I wish you a successful learning process with lots of fun. I thank CPWF for the financial support towards organizing the training workshop that led to the production of this manual and ARARI for their strong collaboration and engagement in the NBDC programme.

Tilahun Amede (PhD)

How to use this manual

The objective of the 5 day training for which this manual has been developed, is not only to teach basic manipulation of GIS, but also enable participants to increase their GIS skills on their own after the training. The manual works with practical exercises that lead the participant through different analyses of GIS so that participants can “learn by doing”.

Each chapter of this manual has three distinctive parts. The first part is theoretical and aims to explain the basic principles of GIS. This part will be presented in a traditional classroom setting. The second part shows how to implement the concepts discussed within ArcGIS. The different analyses of ArcGIS will be discussed in detail as well as the different options available. The third part is the hands-on session, where participants will explore the analyses on their own through a series of exercises.

Exercises are always presented in a text box. The analyses needed to solve the exercise are explained within the text above the box.
** Exercises that have an asterisk (*) in front, are exercises that go beyond the level targeted in this training and are therefore optional. They aims to give additional challenges to participants that already have some basic knowledge of GIS. For these questions steps are not shown in this manual. Often a hint is given, allowing participants to look up the right chapter in the ArcGis helpfile, accessible by pressing F1.*

Participants will be supported by trainers (at least 1 trainer for every 5 participants) to explain in a personal and individual manner the concepts or analyses that are not well understood. This approach allows each participant to learn in their own way and at their own pace.

Every 2 hours, the exercises are discussed in plenary and trainers ensure that all the participants have fully understood the challenges of the exercises

This manual is printed one side only, so that the participant can make their own notes on the left page.

* advanced GIS topics

This manual contains more content than is feasible to cover in 5 days. Some chapters have an asterisks in front suggesting that this content is beyond the basic knowledge of GIS. On the last training day, participants will be able to choose from this list, which of the more advanced topics is most useful to her/him. Participant can also bring their own data with their own challenges to be solved during this day.

Program day by day

Day 1	Program
8.30-10	Introduction to the course objective Chapter 1
10-10.15	Break
10.15 – 12.00	Chapter 2
12-14	Lunch
14-15.30	Chapter 3
15.30-15.45	Break
15.45-17.15	Chapter 3
Day 2	
8.30-10	Chapter 4
10-10.15	break hand in your personal GIS related issue for the final day
10.15 – 12.00	Chapter 4-5
12-14	Lunch
14-15.30	Chapter 5
15.30-15.45	Break
15.45-17.15	Chapter 6
Day 3	
8.30-10	Chapter 7.1
10-10.15	Break
10.15 – 12.00	Chapter 8
12-14	Lunch
14-15.30	Chapter 8
15.30-15.45	Break
15.45-17.15	Introduction to chapter 9 Install the GPS related programs
Day 4	
8.30-12	Excursion including the use of GPS
12-14	Lunch
14-15.30	Chapter 9
15.30-15.45	Break
15.45-17.15	Chapter 9

Day 5	
8.30-10	Choose your advanced GIS topic
10-10.15	Break
10.15 – 12.00	your advanced GIS topic
12-14	Lunch
14-15.30	Choose your advanced GIS topic
15.30-15.45	Break
15.45-17.15	Evaluation Diploma distribution

Discussion and exercise solutions

After each coffee and lunch break, the exercises from the chapter indicated in the preceding timeslot will be discussed in plenary. Participants will be asked to discuss how they solved the exercises. Trainers will make sure that each participant has understood the minimal level of GIS knowledge that is contained within each particular chapter.

Final day

The program on the final day is free. Participants can choose an advanced topic (see below) presented in the manual or identify their own GIS related issue. Those who would like to work on their own issues/challenges during this session are requested to formulate their questions by the afternoon of Day 2 and give them to one of the trainers. The trainers will then undertake a review of the requested topic and assist the participant in finding the relevant data before the final day of the training course.

Participants can also choose to finish or review the exercises already undertaken during the week.

These advanced topics are:

- Geo-referencing
- Vector data entry and editing
- Introduction to raster data analysis

1. Introduction to GIS

The acronym GIS stands for Geographic Information System. *A GIS is described as the organised collection of computer hardware, software, geographic data and personnel designed to effectively capture, store, update, manipulate, analyses and display all forms of geographically referenced information*. A GIS is involves the interaction of **tabular** and **spatial data**, where the tables contain information related to map features. For this reason, we often speak of ***Relational Databases*** when discussing GIS.

1.2 *Tabular Data*

Tabular data consists of *attribute tables* that define the parameters of the map features. There is really no limit to what the tables can contain, whether Boolean strings (True/False), Text, or Numeric data. For example, a Boolean entry in a cities table may define whether or not each city is a national capital. A text entry may have the city's name, or the archaeological period in which it flourished. A numeric entry could have population figures or lat/long coordinates. The advantage of the relational database system is that the different columns can be sorted and selected according to the user's need. These selections then appear highlighted on the map.

Attribute Data thus relates descriptive and numeric data to physical features. Attribute data is related to physical features or locations through a common field often called a relate item. The relate item must be the same type of field. A field can have one of three data types; string (a combination of letters), numeric (a combination of numbers) or binary, (value 1 or 0).

1.3 *Spatial Data*

Digital representations of spatial data must provide a means of storing the data to allow:

- fast retrievals when drawing or printing
- maintaining spatial relationships such as adjacency and intersection
- incorporating non-spatial data associated with locations.

Spatial data places the features on the map. The coordinates of a point are the most obvious example of this, but it also incorporates projection systems, line and polygon attributes, and other information. There are two main classes of spatial data: vector and raster.

Two types of representations are commonly used; vector and raster. The two methods have their own strengths and weaknesses in terms of storage requirements, ease of spatial computations and analyses

and output quality. An ideal GIS would seamlessly incorporate both data types, using each when appropriate and largely hide from the user any distinctions. Unfortunately there is no ideal system.

1.3.1 Vector and raster data

Most work archaeologists do in GIS, for example, is based on vector data. This system of recording features is based on the interaction between arcs and nodes, represented by *points, lines, and polygons.* A point is a single node, a line is two nodes with an arc between them, and a polygon is a closed group of three or more arcs. With these three elements, it is possible to record a wide range of information.

Raster data is characterized by pixel values. Basically, a raster file is a giant table, where each pixel is assigned a specific value of a target information. The meaning behind these values can be elevation in the case of topography, and cell values in a temperature surface represents temperatures etc. Satellite imagery raster are as a result of a reflected or emitted electromagnetic energy that comes from a target. Raster data is advantageous to vector data in constructing 3D images, as the values for every pixel are calculated through a process called interpolation. In ArcMap, it is possible to control what type of interpolation method is used when converting from vector to raster data. Other programs, such as ERDAS Imagine, are tailored specifically to raster data and may be more appropriate for certain projects.

1.4 *Geographic database*

The database is the main difference between a GIS and simple computer mapping application which can only present graphics. Thus any contemporary GIS will incorporate a data management system to visualize and query the database. The creation of a GIS database involves the collection and input (e.g. digitizing, or scanning) of spatial data, and enables the visualization, spatial querying and analysis of this.

A GIS map is made up of layers, or collections of geographic objects. Layers may contain “features” (geographic objects, e.g. rivers or lakes), or “surfaces” (an ocean for example is not a collection of geographic objects but a single continuous expanse that changes from one location to another according to depth of water; this kind of data is called a surface). Geographic objects vary in shapes and sizes but can all be represented in one of three geometric forms i.e. points, polygons and lines.

Polygons represent things large enough to have boundaries, e.g. countries; lines represent things too narrow to be polygons such as rivers or roads. Points are used for things too small to be polygons or lines such as schools or cities. These representations are together referred to as vector data.

A GIS links the spatial objects i.e. features with their descriptive information which is stored as attributes in an attribute table. A GIS can also use the stored attributes to compute new information about the map features. The GIS thus goes beyond simply drawing maps by providing three pieces of information about every feature: what is it, where is it and how does it relate to other features? This gives GIS a niche above other data management systems.

1.5 *How does a GIS provide answers?*

This could be through the display of base data or the derivation of new data through the application of a model. The model is structured as a set of rules and procedures to derive new information that can be analysed with a tool such as ArcView to aid in problem solving and planning. Analytical tools in a GIS are used for building spatial models. Models could include a combination of mathematical/ logical expressions and criteria for the purpose of simulating a process. For this reason a GIS will incorporate a broad selection of tools to perform various kinds of analyses on a spatial database. This process is referred to as spatial analysis.

In GIS there are numerous types of spatial analysis including;

- Proximity analysis
- Spatial overlays
- Contiguity analysis
- Boundary operations
- Surface analysis
- Network analysis
- Pixel based analysis
- Kriging based on interpolation of point data

1.6 *The different applications available in ArcGIS*

ArcGIS consists of different applications:

- ArcCatalog:
  ArcCatalog allows the user to easily access and manage geographic data that is stored in folders on local disks or relational databases which are available on the user's network. Data can be copied, moved, deleted, and viewed before being added to a map. In addition, metadata can be read or created using this ArcGIS application.

- ArcMap:
  ArcMap allows the user to display and query maps, create quality hardcopy maps and perform various spatial analysis tasks. ArcMap provides an easy transition from viewing a map to editing its spatial features.

- *ArcToolbox*
  ArcToolbox provides an environment for performing geoprocessing operations (i.e., operations that involve alteration or information extraction). Tools step the user through the many geoprocessing tasks. ArcToolbox is embedded in both ArcCatalog and ArcMap.

1.7 *Installing ArcGIS on your computer*

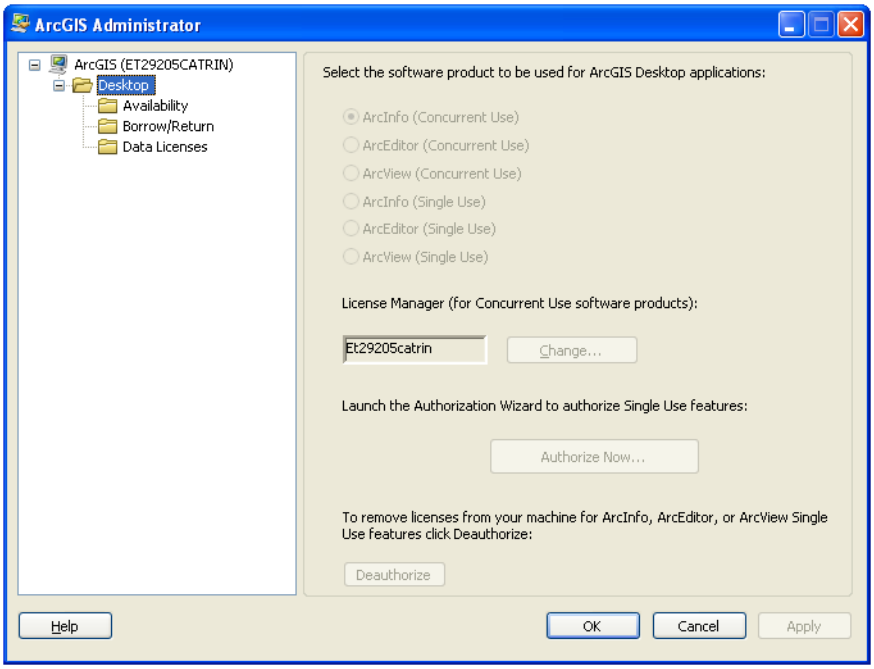
Installing GIS requires installation of the different applications. To install ArcGIS you need to have a copy of the software (provided on a DVD from ESRI (the producer of ArcGIS)) as well as a license file.

Depending on which version of ArcGIS you are installing and what type of license your organization has, installation can look very different. Therefore follow the instructions in the help file which comes with the installation DVD.

For any version of ArcGIS you need to make sure that you have uninstalled any previous version of ArcGIS first. Once this has been done open the ArcGIS DVD, and it will lead you through the installation process. The minimum installation always consists of the *desktop application* and the *license manager*. Install the license manager first, and then the desktop application. In this order the desktop application will then recognize the license manager automatically and avoid needing to link the desktop to the license manager after installation.

Once you have installed the 2 applications, you will find ArcGIS on your computer → start menu → all programs → ArcGIS. However the program will not work yet because the license file has not yet been entered. Therefore, you need to open Arc Administrator start menu → all programs → ArcGIS → Administrator.

In the Administrator, click on Desktop and choose the type of license you have. The installation of the license is very different depending on the type of license. Follow the procedure that is described with your specific license file.



1.8 *Where to get help?*

ArcGIS has a help file. You can access it via the help menu or by pressing F1. You can also access the online help at the ESRI website (the company that sells ArcGIS) via the help menu “Arc Desktop resource center”.

2 ArcCatalog

ArcCatalog has two purposes. Firstly, it allows you to manage, access and explore existing geographic data irrespective of the format in which the data is stored or its location, whether on local discs or elsewhere on the network. As such its purpose is similar to Windows Explorer, but specifically aimed at Geodata. Secondly, you can use ArcCatalog to change the structure of the data, for example to create a new geodatabase, to load existing data into your geodatabase, or to delete or add fields in the attribute tables.

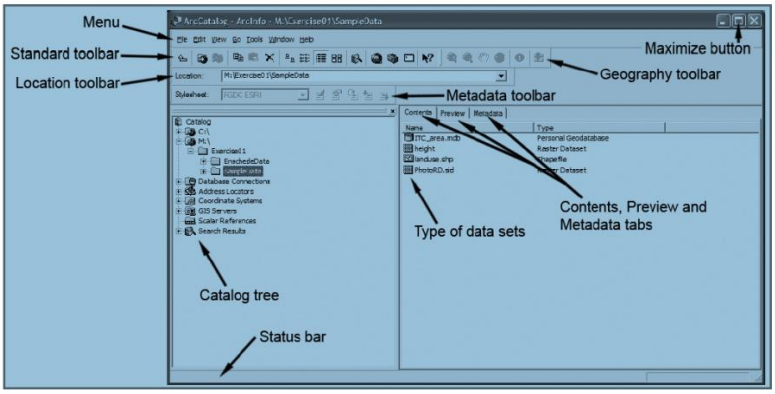
2.1 *Connecting your GIS data to ArcCatalog*

When you open ArcCatalog you will need to indicate where your geographical data are stored, by connecting to the relevant folders.

Launch Arc Catalog:

Start → All programs → ArcGIS →ArcCatalog

The ArcCatalog window



Create a Folder Connection:

From the standard toolbar, click the “Connect to Folder” button:

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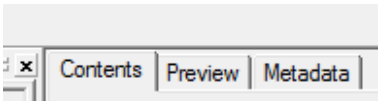
If would like to access it more quickly, you can create and save a connection to your data.

2.2 *Checking your geographical data*

In ArcCatalog, select the file you would like to know more about. You can then look at the data by switching between the “Contents”, “Preview” and “Metadata” tabs.



The “Contents” tab tells you about the type of data you have (vector or raster). The main icon types in ArcGIS are:

For vector data:

- Polygons 
- Lines 
- Points 

Vector data saved in ArcGIS format are referred to as a “shapefile”.

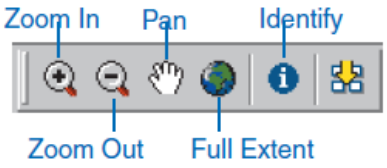
For raster data:

- Grids 

For table data:

- Tables 

“Preview” displays the map of the data you are looking at. You can explore the preview with the following tools:



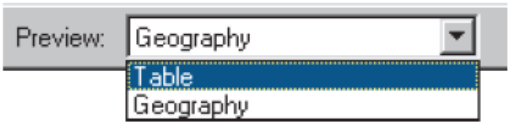
The “Zoom In/Out” button allow you to control the level of detail or the extent of the area to be examined

The “Pan” button allows you to drag the display in any direction. This tool is especially handy if you have zoomed into an area and you want to see different parts of the data at the same scale which fall outside the current display area.

The “Full Extent” button allows you to return to the full extent of the data

The “Identify” button allows you to retrieve the attribute information for a selected feature.

If you wish to preview the data in table format instead of the map you can switch from the “Geography” mode to the “Table” mode:



2.3 *Create a Thumbnail*

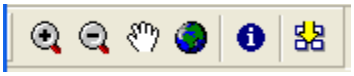
One of the view options in the Standard toolbar is “Thumbnails”. A thumbnail is a snapshot of the geography of a file; however it does not already exist and needs to be created:

To create a thumbnail:

1. In the Contents tab select one of the files.
2. Select the preview tab

ArcCatalog will now generate and display a preview of the geography of the file selected. This preview will now be used to create a snapshot (Thumbnail).

3. From the Geography toolbar select Create Thumbnail and click once.



4. Next, return to the Contents tab and notice the icon has changed into mini-image of the preview.

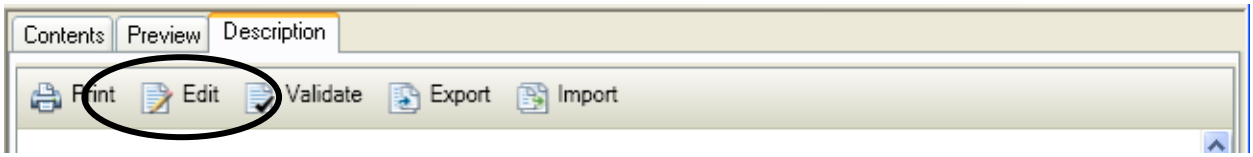
2.4 *Metadata*

Metadata is information about data. It describes details about the data so it can be used intelligently and in an appropriate manner. This includes information on where the data came from, what the accuracy and precision are, who created or modified the data, the year of collection, who is allowed to make use of it, what the units of numeric data are and any published information on the data.

A series of standards for spatial metadata have been developed by a committee composed of academic partners as well as spatial software vendors. Metadata is the most important information when data is transferred. Therefore you should always create the metadata when you create your own maps.

There are many ways to introduce metadata. One simple approach is to add a text file to each of your shapefiles and rasters. But ArcCatalog also allows you to introduce data in the quality standard ISO.

In ArcCatalog click on the data, click on the “Description” tag, and choose “Edit” (note that this works in ArcGIS 10, in ArcGIS 9 you need to activate the “Metadata” toolbar, and choose “Edit metadata”).



Exercise 2-1

1. *Click on the first file "woreda". What type of data is it? (vector or grid based?) Can you preview the data? What does the metadata tell you? How many attribute does this map have? Can you create a thumbnail?*
2. *Do the same with the "towns_amhara" file. What type of data is it? What is the difference between this and the previous dataset?*
3. *Look at the file "dem_ethiopia". What does this file show? What is the difference with the two previous files you looked at and this one?*
4. *Look at the files "RR", "Tmax", "Tmin". What type of file are they? What are the spatial characteristics of these files?*
5. *Choose one file, for which you indicate in the metadata that the file is used for training purposes.*
6. *What are the reasons for creating and adjusting metadata?*

3 Basic Concepts and Operation of ArcMap

3.1 *Launching ArcMap*

ArcMap is the ArcGIS interface that allows you to create your own maps. There are different ways to launch ArcMap:

1. Start All programs → ArcGIS →ArcMap (like ArcCatalog)
2. In ArcCatalog, click this symbol on the menu bar:  .

When opened for the first time ArcMap has three windows; a table of contents, the toolbox, and the mapping window.

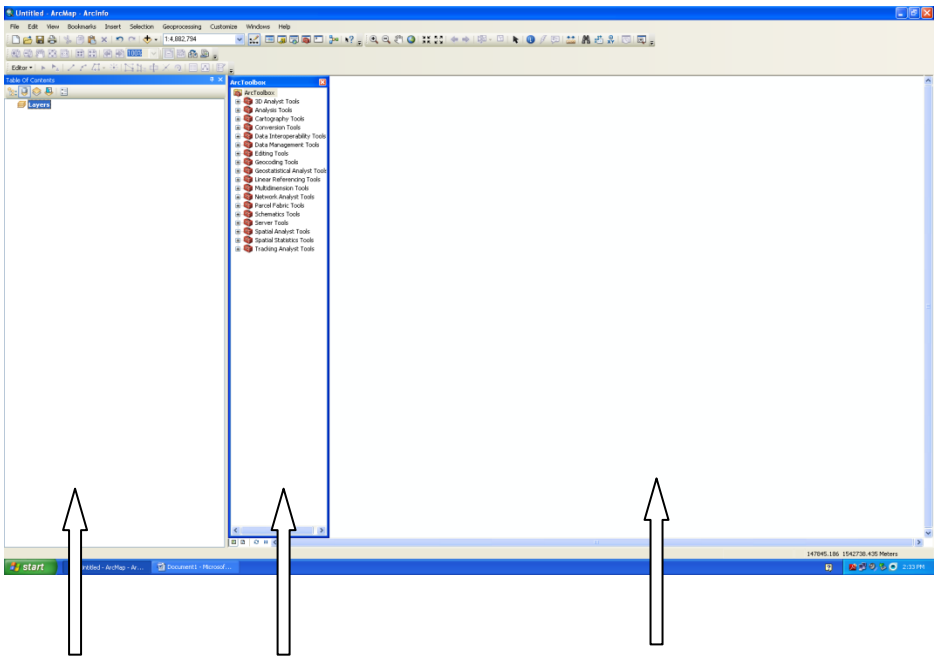
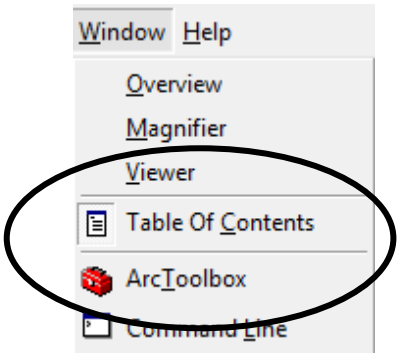


Table of Contents Arc Toolbox Map window

Note that if these tools do not appear you can request them from the "Window" menu in the tool bar:



3.2 *Adding data*

At this stage, you will learn to add existing geographical data. If you want to create your own geographical data, please refer to "Creating and editing vector data" in Chapter 10.

You can load data to your map in two ways:

1. Click the "Add data" button  and select the folder with geographical data ("geodata"), select the data you want to load and click ok.
2. If ArcCatalog is open select the geodata you want to map and drag it (take it with your mouse) to the ArcMap table of contents window

The data you have added are referred to as a "layer". This layer can be activated or deactivated by clicking on the box next to the layer name :  . The collection of layers which are used to create a map are collectively referred to as the "data frame", represented in ArcGIS with the symbol 

.

At the bottom of the Table of Contents there is a Display tab, a Source tab, and a Selection tab.

When you select the "Display" tab, you will be able to see the drawing order of the layers and you can move a layer up or down in the Table of Contents by dragging and dropping it.

When you select the "Source" tab, layers are sorted by where they are stored on disk. This is useful during editing when you want to edit all layers in a given folder or database. You cannot change the drawing order of layers when the Source tab is selected.

The "Selection" tab allows you to choose the layers from which features can be selected.

Exercise 3-1

1. *Launch ArcMap*
2. *Load the "woreda" shapefile. What do you see? Can you see Lake Tana?*
3. *Load the "towns_amhara" shapefile. Can you see the map? What does it show?*
4. *Rearrange the order of the layers. Which is the smartest order to organize your layers?*
5. *Switch off (take away) the towns from your map*
6. *Can you identify the source directory of the layers?*
7. *Guess which point is the town of Bahir Dar*

3.3 *Exploring your map*

3.3.1 Moving around your map

Similarly to ArcCatalog you can move around you map and zoom in and out, pan across and return to the full extent using the following tools: 

You can also return to the full map extent by right clicking on the layer and selecting “Zoom To Layer”.

You can use the magnifier window:

- In the menu, click “Window Magnifier”
- To move the window, click the title bar of the window and drag it
- To change the magnification percent, right-click on the title bar and select “Properties”

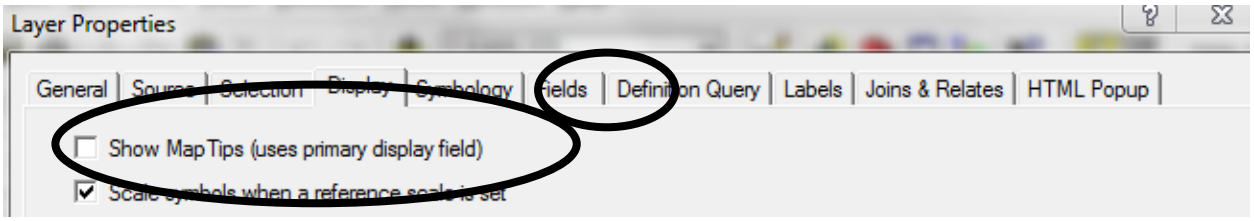
3.3.2 Interacting With map features

You can also explore your map with the “Identify” tool  . This tool allows you to click on a feature and get the record for that specific feature.

You can also activate the “map tip”. As you hold the mouse pointer over a feature, the “primary” field will be shown. This provides a quick way to see the name of a feature or a particular piece of information without having to use the “Identify” tool.

To activate the “map tip”:

- Open “Properties” (double click on layer)
- Select tab “Display”
- Activate “Show map tips”



3.3.3 Measuring Features

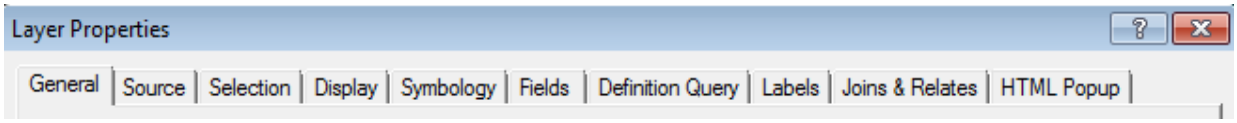
You can measure distances on your map with the “measurement tool”  . Click on this button and select a starting and an end point on your map. The distance will be shown in a window. Exit the measurement tool by double clicking on your map.

3.4 *Map properties and symbol colors*

As a first stage, you should examine the properties of the data you have loaded. You might also want to change the colors of your maps. This is done under the properties of a layer:

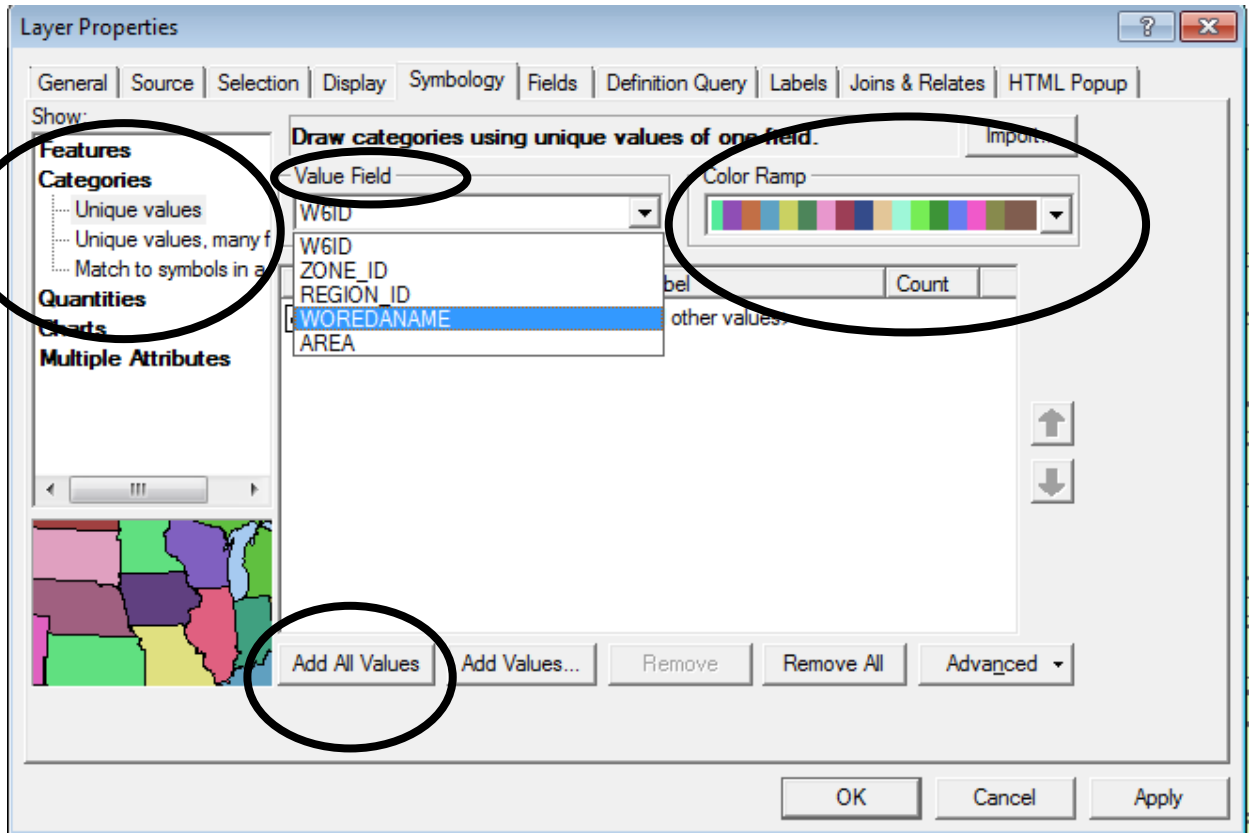
- Select the layer you want to explore
- Double click on the layer OR right click on the layer and click “Properties”
- A window will open that allows you to see the different properties of the layer including: “General, Source, Selection, Display, Symbology, Fields, Definition Query, Labels, Join & Relates and HTML”. You can switch between them by clicking on the corresponding tab.

We will come back to all of these options later on in the manual. In this chapter we will only look at “General”, “Source” and “Symbology”.



The “General” tab gives you similar information to the one in ArcCatalog – i.e. information about the data. The “Source” tab tells you where the data is saved, as well as which coordinate system the data is in. This manual contains a separate chapter on coordinate systems and projections. At this point just note that if the coordinate system is <undefined>for your dataset then you need to address this (see the chapter on coordinate systems).

The “Symbology” tab allows you to change the colors used in the maps. Using a ‘Single symbol’ to display features is not always very useful as it treats all of the features the same. If you wish to be able to distinguish between different features in a single layer on your map, you can change this by using “categories” following the instructions below:



- Select the “Symbology” tabs
- Select the “Categories” option on the left
- Select the “Value Field” (this is the variable you want to map)
- Select the “Colour Ramp”
- Click “Add All Values”

Once you have done this you can adjust the color for each category if you wish by clicking on the corresponding color. You can also press ctrl shift and select different categories, and right click to group them. The same window allows you to map quantities or charts instead of categories.

Exercise 3-2

In the "woreda" map you loaded in the previous exercise:

1. *Give each woreda a different color*
2. *Give all of the woredas within a single zone the same color*
3. *Color Tana lake in blue. What challenge are you facing?*
4. *Make all the woredas from Amhara and from Oromia the same color*
5. ** Make a woreda map that shows the woreda where you come from in one color and all the other in another color. (hint : use "add values"*
6. **Make a woreda map that shows population of each woreda. (hint : use quantities instead of categories). What is the difference with the previous map?*
7. **Load the "town_amhara" shapefile and make a graph for each town showing population. Which graph makes sense? (hint : use charts)*

3.5 *Save your work*

You can save your workspace as a "project". This will maintain all of the individual changes you have made to your map, and when you reopen the project you can continue working where you stopped. However you should note that it only saves the links to the shape and raster files. So if you change computers don't forget to copy the data files too. Your project file will have the name you have specified, followed by the extension ".mxd". If you save the map created in the above exercise as the project file "Tanabasin.mxd" on a portable disk drive and move it to a different computer, opening "Tanabasin.mxd" will show you the datasets in the table of contents, but your data view and layout view will be empty. This is because the file "Tanabasin.mxd" doesn't hold the data. It only holds the instructions on where to find the data, and what symbols to use when displaying the data, among other information. If you haven't also moved your data to the new computer, then there will be nothing for the project file to display. It is recommended to save the map project (e.g. "Tanabasin.mxd") in the same directory as the data so that you can easily move both the "Tanabasin.mxd" map project and the data the same time. It is also possible to use the option to 'store relative path names for data sources' before you save the map document. This option helps the map document to read the data sources when you have moved them.

To set relative path names go to the "File" menu and select "Map document properties" and tick "Store relative names to data sources".

Exercise 3-3

1. *Save your work in a project, so that you can continue working with it in the next days.*
2. *Change the name of one of your layer, by clicking once on the name. Did the name of your data file change? (Hint : use propreties → source)*
3. *Use window explorer and find the woreda shapefile. How many files are needed to map a shapefile?*
4. *Copy all the files related to the woreda shapefile. Change the name of the.dbf file. Try to load the "woreda copy" file. Does it work? Delete the copied file.*
5. *Go to ArcCatalog, copy the woreda file, name it woredabis. Check what happened with windows explorer.*
6. *What do you learn from the previous procedures?*

4 Tabular data

4.1 *Attribute tables*

An “attribute” is non-spatial information about a geographic feature in a GIS, which is usually stored in a table and linked to the feature by a unique identifier. For example, the attributes of a river might include its name, length, and sediment load at a gauging station. In raster datasets, the attribute table indicates the information associated with each unique value of a raster cell.

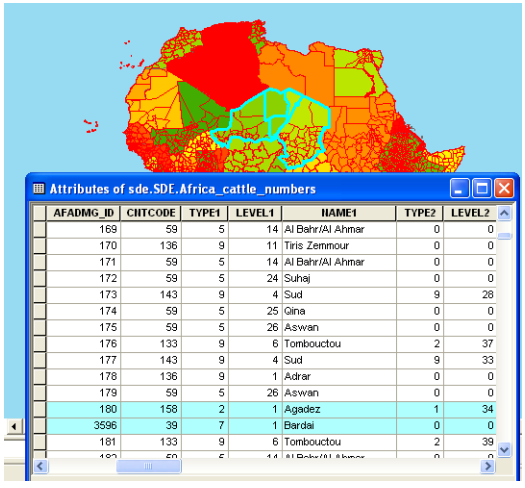
4.2 *Connecting features to attributes*

The major power of a GIS lies in the link between spatial (graphic) data and the tabular (descriptive) data. There are three important characteristics of these connections;

1. A one to one relationship is maintained between the features on the map and the records in the feature attribute table
2. The link between the feature and the record is maintained through a unique identifier assigned to each feature
3. The unique identifier is physically stored in two places: in the files containing the x,y coordinate pairs, and with the corresponding record in the feature attribute table.

To access the attribute table right click on the layer and select “Attribute table”. You should be able to see all the data in your file which is stored in the attribute table. The table is divided into records and fields that are represented as cells. Every single geographic object (a feature) has its own record in the table (a line). If you select one of the features in the attribute table, this feature becomes selected (highlighted in blue) in the map.

You can also proceed the other way round by selecting the feature on the map. The information in the attribute table which corresponds to the specific feature you have selected on the map will be highlighted in blue in the attribute table as shown in the picture below.



To select features in your map you can use the “Select Features” tool: 

- Click the “Select Features” tool in the tool bar
- Right click on the layer from which you have built a selection and select “Open Attribute Table”
- Click on the “Show Selected” button at the bottom of the window

All selected features will be grouped together in the window.

4.3 *Changing table properties*

4.3.1 Column width

Depending on the font, size and length of records it may happen that not all information is initially readable. In these cases the width of the column has to be altered. To change the width of a column:

1. Position the mouse over the extreme right edge of the column heading (notice the pointer cursor changes)
2. Double -click the left mouse button. The column width will now be adjusted to the width of the longest entry in that column
3. Alternatively, you can click and drag the edge of the column to an acceptable width and release the mouse

4.3.2 Column position

Sometimes tables contain many columns. In order to work efficiently you may have to rearrange the columns and to position the ones you need next to each other.

To reposition a column:

1. Click the column heading
2. Click the column again and hold down the mouse button
3. Drag the column heading to the location between the columns (notice a red line indicates the new location of the column)
4. Release the mouse button

4.3.3 Freeze a column

Sometimes it is very helpful if a column that you wish to compare to other columns remains at a fixed position while you scroll horizontally through the table. This process is called freezing a column.

To freeze/unfreeze a column:

1. Right click on the column heading (i.e the column you want)
2. Click “Freeze\Unfreeze Column”
3. Move the horizontal slider - the column will remain fixed at the beginning of the table.

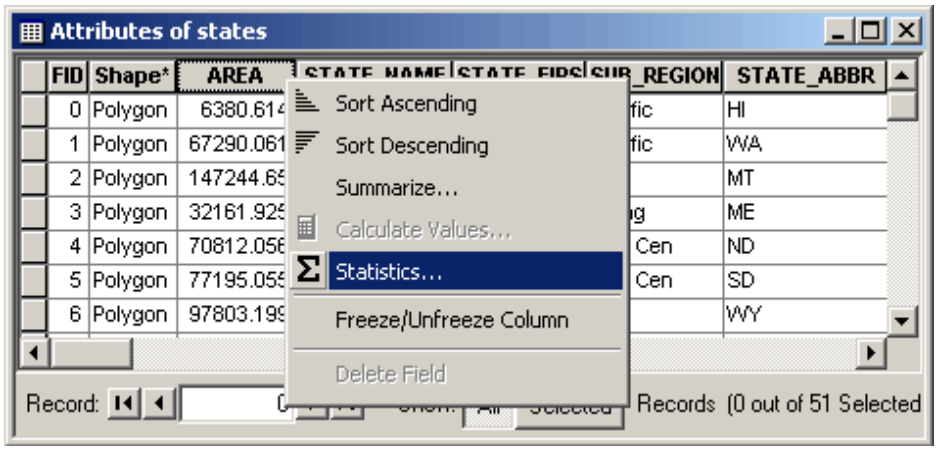
4.3.4 Sorting columns

If you need to rearrange the records in a column in an alphabetical or numerical order, proceed as follows:

1. Right-click the column you want
2. In the drop-down list, click “Sort Ascending /Descending”
3. Scroll down the list and notice the change

4.4 *Calculating Statistics*

Various statistics can also be computed for a particular attribute field. To perform this operation, right click on the field of interest, and select “Statistics”.



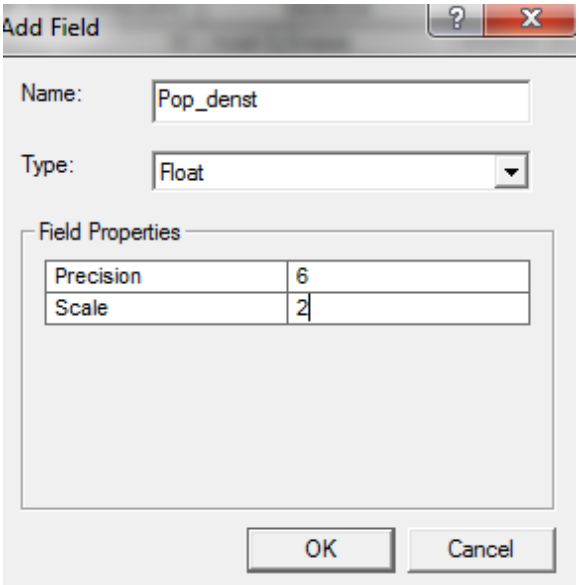
A dialog box will appear with the statistics for the selected field. The statistics box displays the number of records in the table and the minimum, maximum, sum, mean, and standard deviation values. The frequency distribution chart represents the distribution of values graphically.

Exercise 4-1

1. *Open the attribute table for the " town_amhara" shapefile*
2. *Which are the 3 biggest towns in terms of population? (hint use the "sort" option)*
3. *Select these 3 towns in the attribute table*
4. *Which woreda are they in (hint use "woreda" shapefile and activate map tips)?*
5. *Freeze the column "'woredaname". Move across the attribute table. What is the purpose of freezing column?*
6. *Find the town of Bahir Dar by using the identify tool.*
7. *Select all of the woredas around Lake Tana.*
8. *How many woredas have you selected? (hint use "show selected" in the attribute table)*
9. *Export these woredas into a new layer and name it "tanaworeda"*
10. ** What is the total area of the selected woredas? (hint use "Statistics")*

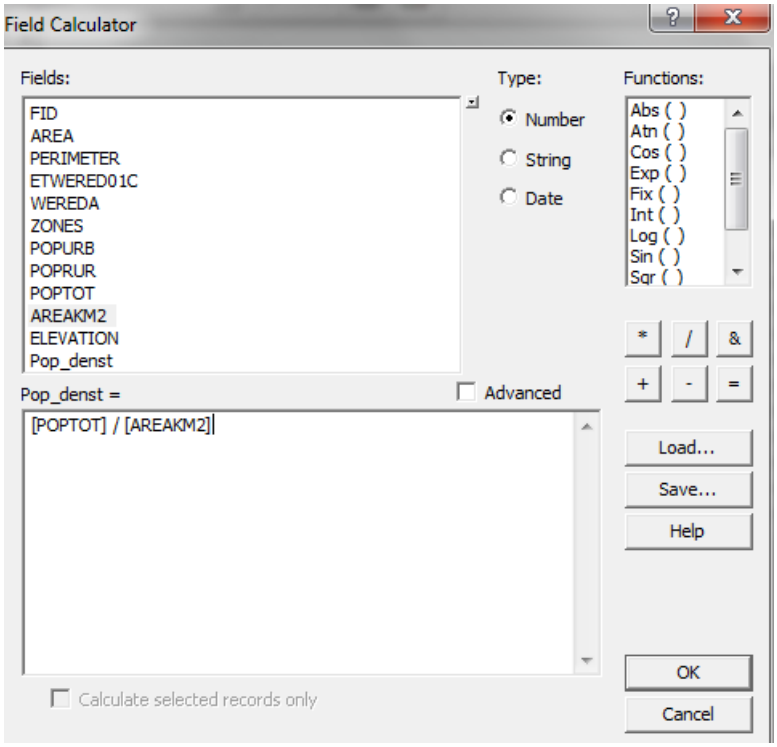
4.5 *Adding fields to an attribute table*

- One way to add your own data is to edit the attribute table and add fields. Open an attribute table
- Click the "Options" button and select "Add Field". The Add Field dialog box will appear.
- Type a name for the new field and indicate the format of the new field.



A Float is a number with a decimal. The “Scale” indicates how many decimals the number will have and “Precision” indicates how many numbers can be entered in this field.

- In the attribute table right click the heading of the new field and choose “Field calculator”. ArcMap will automatically ask you if you want to work outside an editing session. Say yes.



- Enter the computation for your new field.

One alternative to compute the field is to open an “editing session” just before choosing “field calculator. This can be done as follows:

- Activate the “Editor” menu bar as below
- Start an editing session by selecting the “Start Editing” option

When you finish computing your new field you then :

- Save your edits
- Select “Stop editing” to exit the editing mode

Instead of calculating computations between different fields, you can also compute the area or the perimeter. **To do this you need to make sure that your data is projected (see chapter 6)**.

This time instead of selecting the “Field Calculator“ select the “Calculate Geometry” option.

Exercise 4-2

1. *Load the woreda shapefile. Create a new field that indicates population density (density is calculated as population/area).*
2. *Calculate the perimeter of each woreda.*
3. *What is the coordinate system of your data? Why does it matter?*
4. **Calculate the area of each woreda. The woreda file already contains a field called area. Do you find the same values?*
5. **What is the area of Ethiopia? (hint: use the statistics option). If you have internet access compare it with the official statistics.*
6. **What is the perimeter of Ethiopia?*

4.6 **Relational join operations*

Relate uses a common item to establish temporary connections between corresponding records in two tables. In relate, each record in one table is connected to a record in another table that shares the same value for a common item. A relational join on the other hand joins the two tables using the common item. When we need information that is not contained within the current table but in included in another, we can link these tables together based on a common attribute. This is possible when a common attribute exists (identifier) in both the tables.

In ArcMap you can establish this kind of link by either joining or relating tables:

Join: when two tables are joined the attributes from one are appended to the other based on a common attribute.

We can join two tables when the data in the tables has a one-to-one or a many-to-one relationship. For example, we have a layer with fields and another layer with farms. In this case, as many fields are in the same farm we say that both layers have a many-to-one relationship.

Relate: Relating tables defines a relationship between two tables. This is also based on a common field, but does not append the attributes of one to the other.

We may want to relate two tables when the data in the tables have a one-to-many or many-to-many relationship between farms and field. One field might also have several parcels with different owners. A parcel may have more than one owner, and an owner may own more than one parcel. Because the relationship is many-to-many relationship, we can relate the data.

** Exercise 4-3*

1. **Open the "atlas" shapefile. What type of data does it contain?*
2. **Which field can be used for join or relate? What does this field characterize?*
3. **Perform a relate with the woreda map then open the attribute table. What do you see?*
4. **Deactivate the relate*
5. **Make a join? Open the attribute table? What is the difference with the relate?*
6. ** Make a map of different socio-economic variables? Choose a woreda you know, does the data makes sense to you?*

5 Selecting features

So far we have only looked at a given feature and how to select it manually. In this section we will investigate other ways to query and select data.

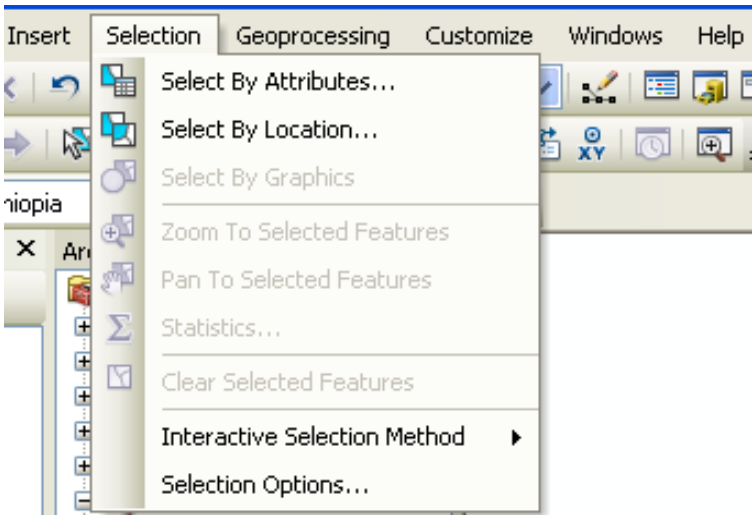
5.1 *Selecting features by attribute*

There are three different ways to select a feature by attribute;

1. The easiest is by sorting the data and selecting manually as explained in the previous section.

2. The second method is by using the "Select by Attribute" in the "Selection" menu

   - Click on the "Selection" menu→ select by attribute



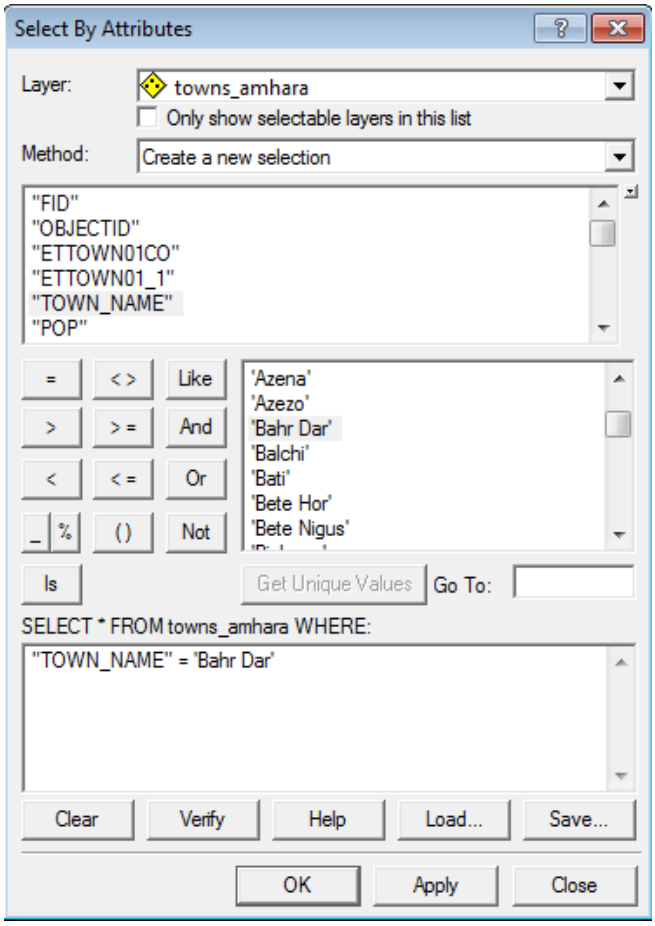
- Indicate which layer you want to select from

Use SQL (structured query language a language used to query database) to define your selection. SQL is a language that allows you to query a database - the SQL query window helps you to express your request correctly. In the top box select the attribute you would like to select from. Then select which condition this attribute should have. To do this you need to select the right Boolean operator (=, >,<) and the condition. You can click to get unique values to select from within the existing values in the database. This is particularly handy when you want to select a string (a name) as it will avoid any typos and automatically retrieves the correct formatting for strings.

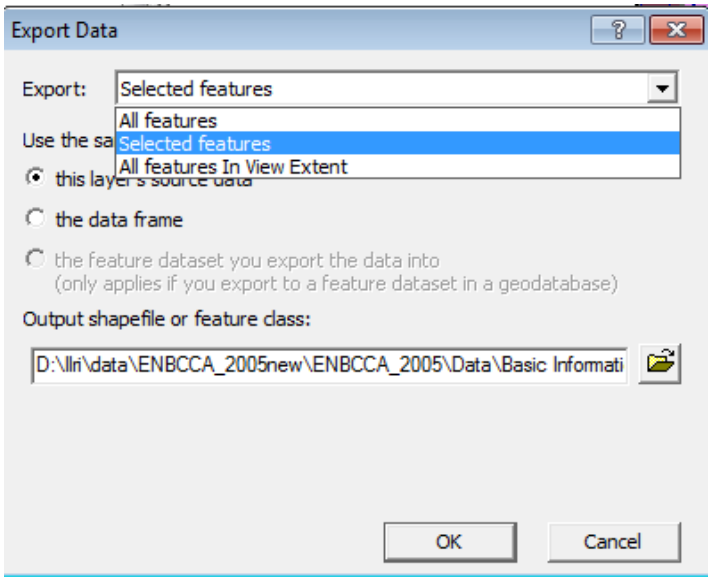
Boolean expressions and their meaning

A Boolean expression is an expression that evaluates to a value: True or False. The most common operators are:

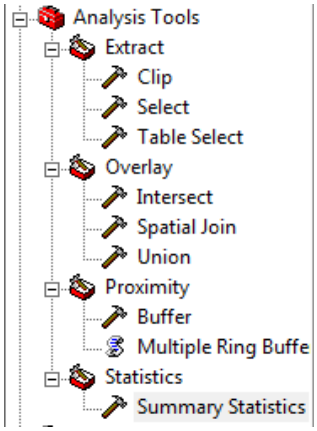
=	equal to
<	less than
<=	less than or equal to
>	greater than
>=	greater than or equal to
<>	greater than or less than
LIKE	is the same as = for strings but allows to guess some of the letters
AND	is part of all the sets
OR	is part of at least one of the set
NOT	is not part of the set



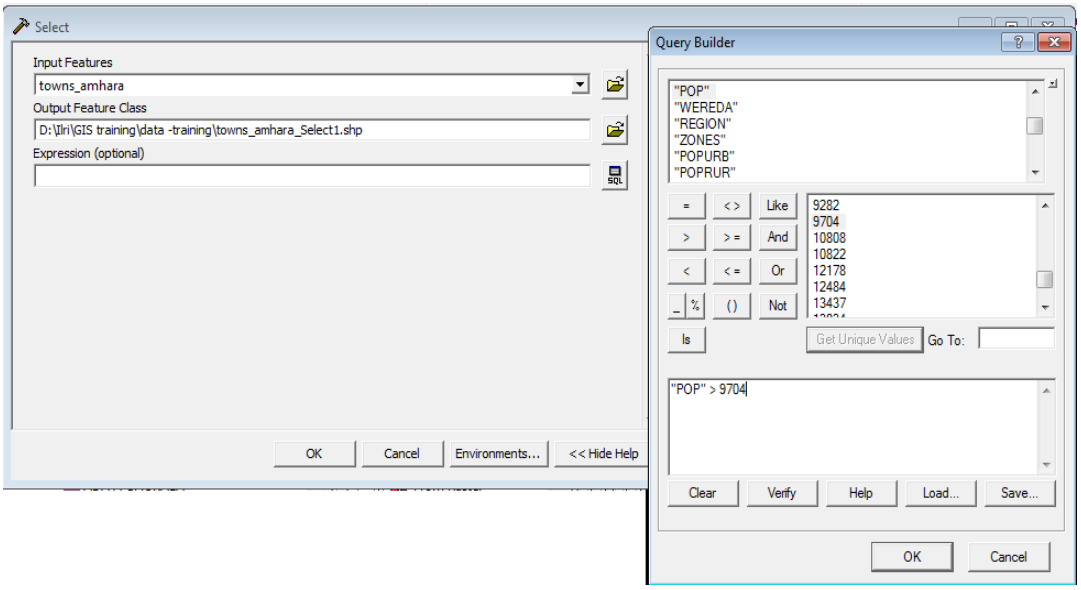
Once you have clicked ok, then the records in the attribute table which corresponds to your query will be selected. You can create a new layer from this data by right clicking on the layer and selecting “Export data”, choose “Selected feature” and indicate the location where you want to save the file.



3. The third option is to use the “Selection” tool in the toolbox (this option directly exports the selected features to a new layer)
    - Make sure that you have the toolbox in your window (see section 4.1)
    - Go to “Analysis Tools” and select “select”



    - Identify the input feature i.e. the layer you want to select from
        - Identify the output feature i.e. the location where you want the new map with the selected features to be saved
        - Choose the expression: click on SQL and the SQL query window will open. Define your query following the method described in the previous section.



Exercise 5-1

1. *Select all towns which have a population greater than 10,000 inhabitants in the "town_amhara" shapefile. Can you select these using 2 different methods?*
2. *Load the "basin" shapefile. Select the Tana basin using the SQL query builder and save it into your folder.*
3. **Select all town bigger than 5'000 inhabitant in the Siemin zone*

5.2 *Selecting by location (Spatial queries)*

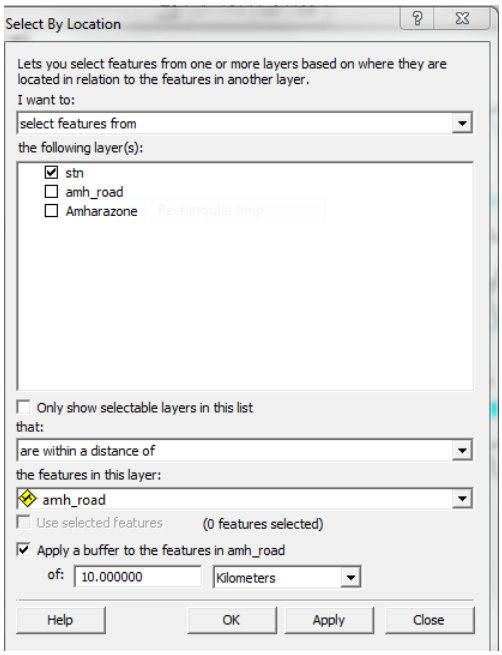
The "Select By Location" query aims to select features based on their location relative to the locations of other features. You would perform this query if, for example, you wanted to identify all of the fields along a particular road. To perform this type of query you need at least 2 layers: a target layer - the layer in which features will be selected, and a source layer - the layer that is used to determine the selection based on its topological relationship to the target. In addition to selecting features this tool also allows you to add or remove features to or from you map.

There are a variety of selection methods available to select the point, line, or polygon features in one layer that are near to, or which overlap features in the same or in another layer. The ArcGIS help file (F1 and then search for "select by location") gives you a very clear and concise overview of the options available. These are listed below:

- Are Crossed by the Outline of: This method selects the features that are overlapped by the features of another layer.
- Intersect: This method selects any features that are overlapped by the features of another layer as well as those features that border the reference features.
    - Are Within a Distance of: This method selects features near or adjacent to features in the same layer or in a different layer. You must specify the numerical distance of interest.
    - Have Their Center in: This method selects the polygon features in one layer that have their centroid in the polygon features of another layer.
    - Are Completely Within: This method selects features in one layer that fall completely inside the polygons of another.
    - Completely Contain: This method selects polygons in one layer that completely contain the features in another layer.
    - Share a Line Segment with: This method selects line and polygon features that share line segments with other features.
    - Touch the Boundary of: This method selects lines and polygons that share line segments, vertices, or end-points (nodes) with the lines in the layer. The lines or polygons will not be selected if they cross the lines in the layer.
    - Are Identical to: This method selects any feature having the same geometry as a feature of another layer; however, the feature types (point, line, or polygon) must be the same.
    - Contain: This method selects features in one layer that contain the features of another. The boundaries of the features ARE allowed to touch.
    - Are Contained by: This method selects features in one layer that are contained by the features in another.

To make use of this tool for the selection of features:

- click “Selection” and “Select by location”
- choose “Select feature from”
- click the dropdown menu and select the selection method, such as “are within a distance of “ or “ intersect”
- click the drop-down arrow and click the layer you want to use to search for the features
- if you use “are within a distance of” then check “Apply a buffer” to the features in <layer> and set the distance within which to search for features



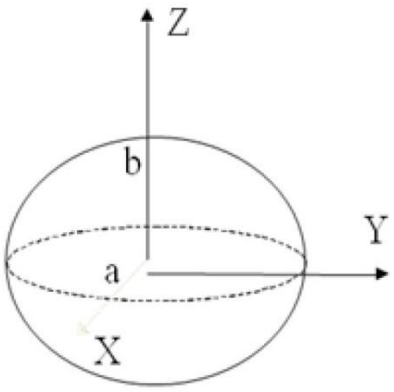
Exercise 5-2

1. *Load the road shapefile and select all woredas which are crossed by a gravel road.*
2. *Load the town_amhara shapefile and select all towns that are within 2km from a road. How many towns did you select?*
3. ** What is a buffer? Do you have an example in the agricultural context for which buffers can be useful?*

6 Coordinate systems

6.1 *General features*

The geographic coordinate system (GCS) uses a three dimensional spherical surface to define locations on the earth. A GCS includes an angular unit of measure, a prime meridian, and a datum (based on a spheroid). The shape and size of a geographic coordinate systems' surface is defined by a sphere or spheroid. Although the earth is best represented by a spheroid, the earth is sometimes treated as a sphere to make mathematical calculations easier. Choosing to use a sphere or spheroid will depend on the intended purpose of the map and the accuracy of the data. A sphere is based on a circle, while a spheroid (or ellipsoid) is based on an ellipse. The shape of an ellipse/ellipsoid is defined by two radii, its semi-major axis and a semi-minor axis.



Because of gravitational and surface feature variations, the earth is neither a perfect sphere nor a perfect spheroid. Whereas a spheroid approximates the shape of the earth, a datum defines the position of the spheroid relative to the center of the earth. A datum provides a frame of reference for measuring locations on the surface of the earth. It defines the origin and orientation of latitude and longitude lines. Coordinates without a specified datum are vague. It means that questions like Height above what?, Where is the origin? and On what surface do they lie? go unanswered. When that happens, coordinates are of no real use. An origin, a starting place, is a necessity for them to be meaningful. Not only must they have an origin, they must also be located on a clearly defined surface. Satellite data have provided geodesists with new measurements to define the best earth-fitting spheroid, which relates coordinates to the earths' center of mass. An earth-centered, or geo centric, datum uses the Earths center of mass as the origin. With increasing demands for global surveying activities, several worldwide useful datum and projections have been developed. The World Geodetic System 1984 (WGS84) is the most famous and widely used of the world wide datums. It serves as the framework for locational measurement worldwide. There are two kinds of worldwide coordinate systems Geographic and UTM (projected) which have been developed on the basis of the WGS84.

6.2 *Geographic coordinates*

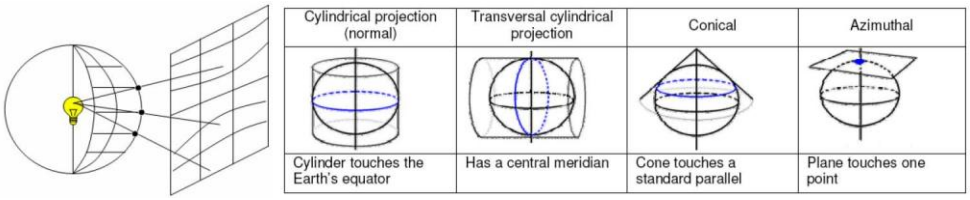
The geographic coordinates represent a position on the surface of the Earth with angles instead of distances and are referred to as longitude and latitude. Usually the angles are measured in degrees, but grads and radians are also used. On the Earth, any two lines of longitude, for example, west longitude 89° 00 00 and west longitude 90° 00 00 are farthest from each other at the equator, but as they proceed north and south to the poles, they become closer. In other words, they converge. It is interesting to note that the length of a degree of longitude and the length of a degree of latitude are just about the same in the vicinity of the equator. They are both approximately 111 km. Lines of latitude are called parallels because they are always parallel to each other as they proceed around the globe. They do not converge as meridians do or cross each other.

6.3 *Projected coordinates*

In order to represent the earth in two dimensions on a map, one must be able to “make the world flat”. This is done by projecting points from the surface of the earth to a plane. Different projection methods exist. Projected coordinates have the advantage that they reflect the metric system and allows us to measure distance between points.

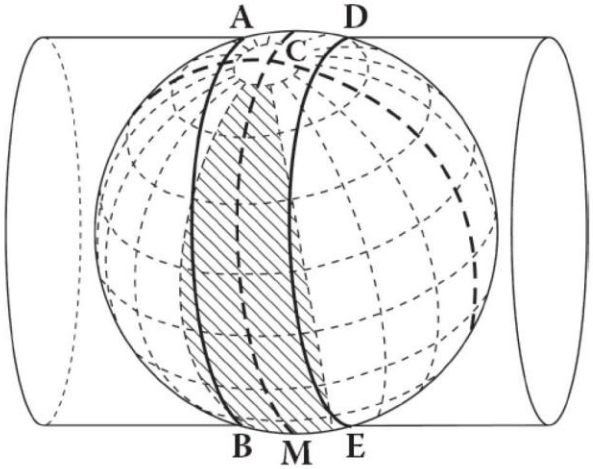
6.3.1 Projections

The term “projection” comes from the notion of placing a light source inside a transparent globe and projecting shadows of the meridians (longitude), parallels (latitude) and other geographic features onto a flat paper map or a computer screen as shown in the left panel of figure below. To do this, one needs to use map projections, which can be seen as different methods to make the round Earth flat. Map projections are mathematical functions, but may be described in the three basic projection forms; azimuthal (plane), conical and cylindrical as shown in the right panel of the figure below.

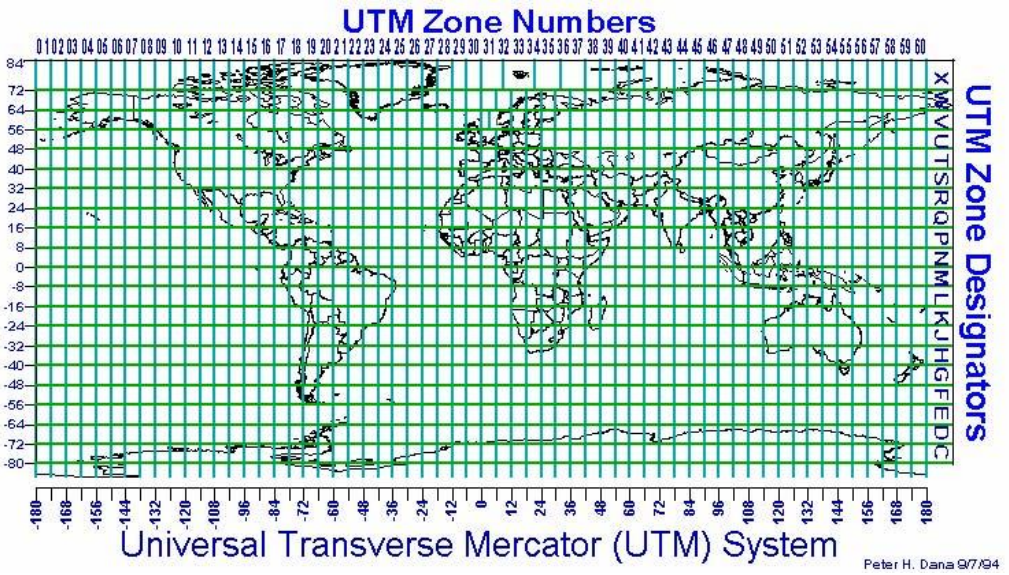


6.3.2 UTM coordinates

The most commonly used approach to project coordinates is the UTM (Universal Transverse Mercator) system. UTM is a Cartesian coordinate system that uses the transverse Mercator projection. This projection results from wrapping the cylinder around the poles instead of around the equator as shown in the figure below.



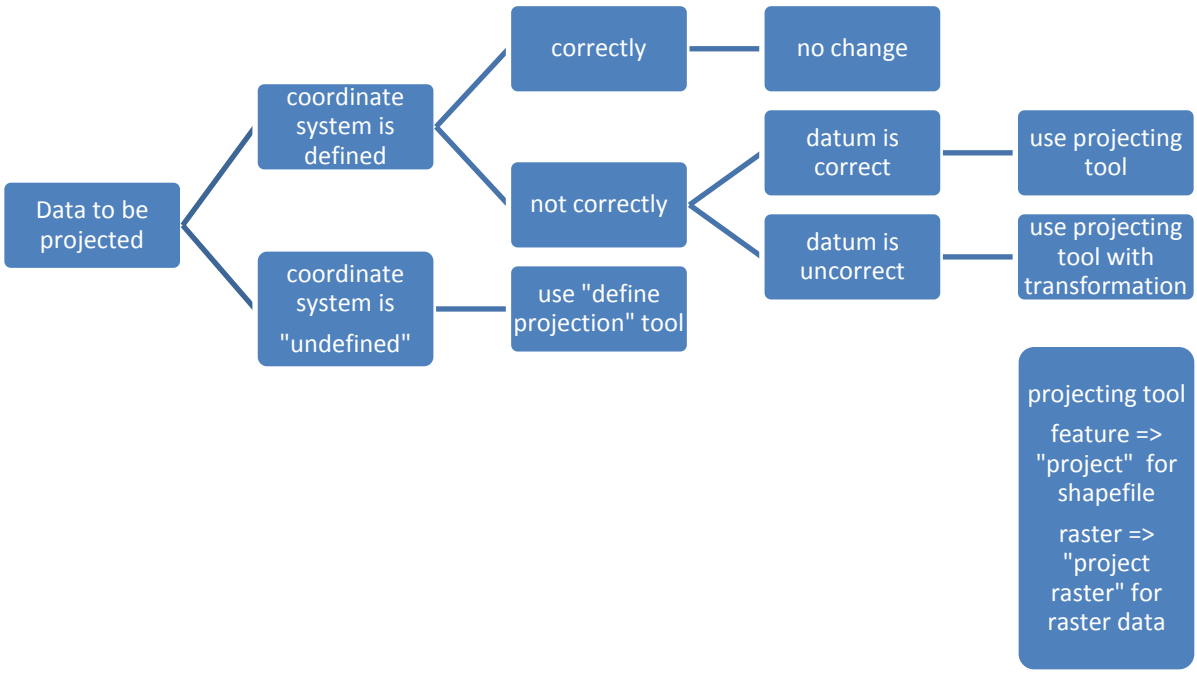
The Earth is subdivided into sixty UTM zones, numbered from west to east, starting with zone 1 at 180'W. Each zone is thus six degrees of longitude wide, and extends from 84'N to 80'S. Displacements in the x and y directions are called UTM eastings and UTM northings, respectively as shown in the figure below. Another point for the utility of the UTM is its coordinates unit. Different to geographic coordinates, the UTM use meter as coordinates unit, therefore it become convenient to calculate length and area. For Ethiopia use 37N zone.



6.4 *Defining and changing projections in ArcGIS*

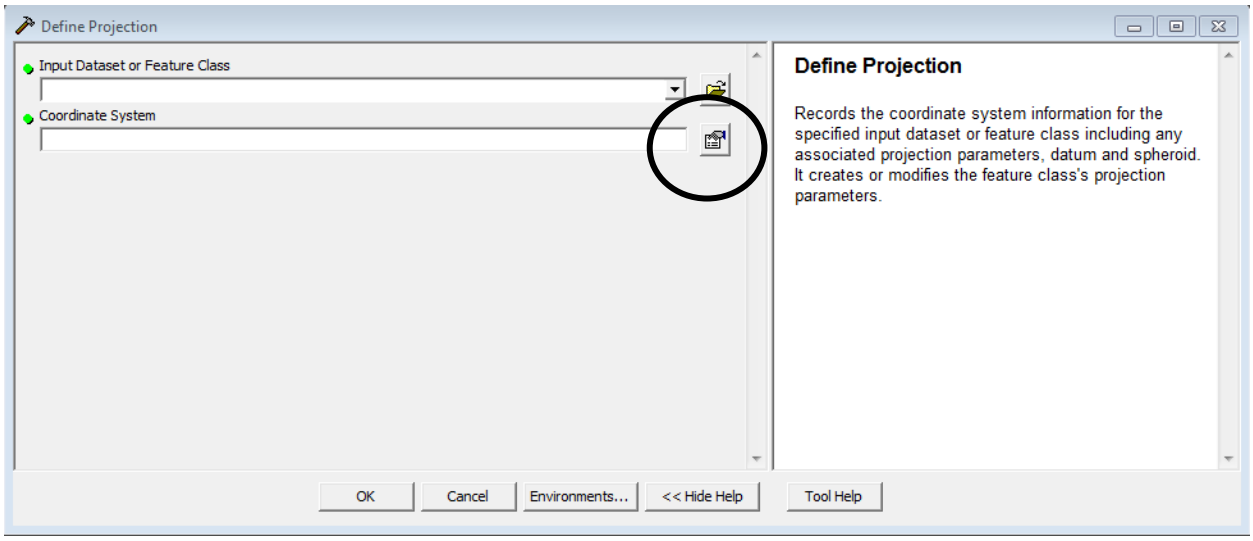
Setting the projection right in ArcGis crutially depends on the intial coordinate system and project of the data. There can be four different situations: 1 the data is in the right projection 2 the data has no projection 3 the data is in the right datum but not projection 4 the data is not in the right datum. For each case another tool in the ArcToolbox has to be used.

First You can check the projection of your data by double clicking on the layer “Properties” → “ Source”. Then you can follow the procedure below :

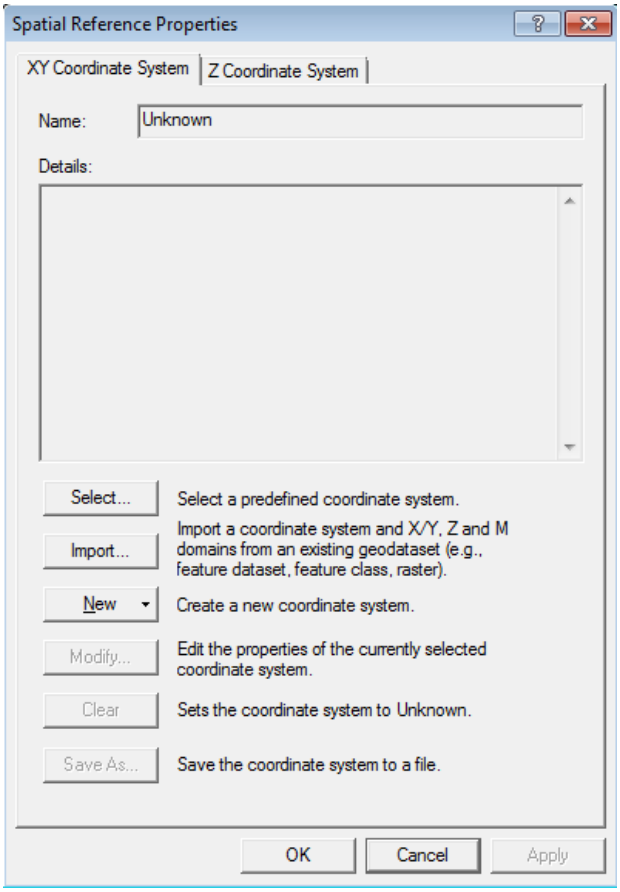


The two simplest cases are, the data is in the right system and already in the wished projection so no change is required, and the data is undefined in which case the data can be projected with the “define projection tool”Go to the toolbox “data management tool” → “projection and transformation” → “define projection”.

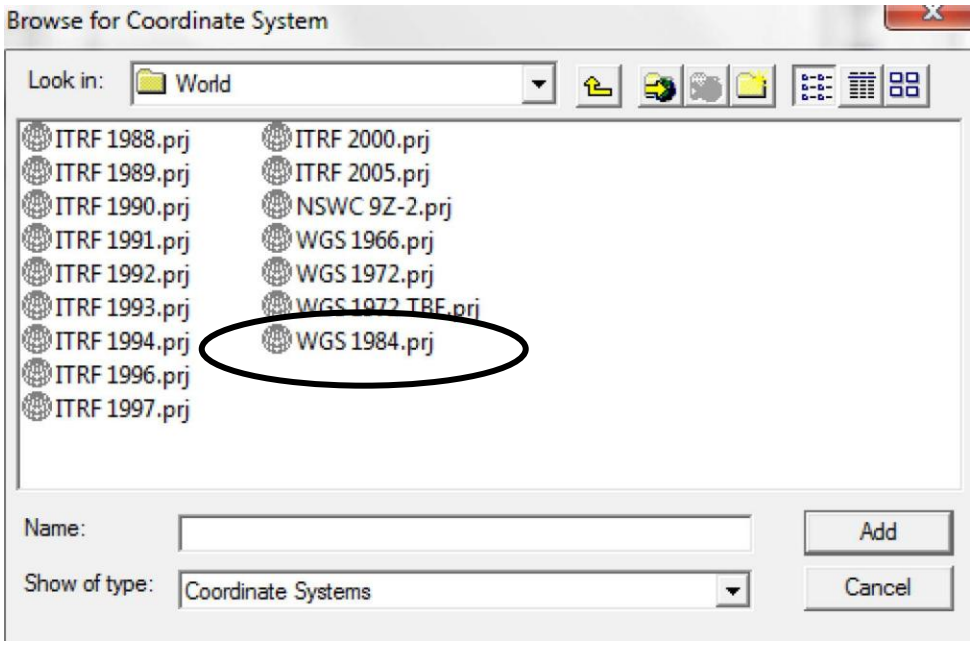
The following window will appear:



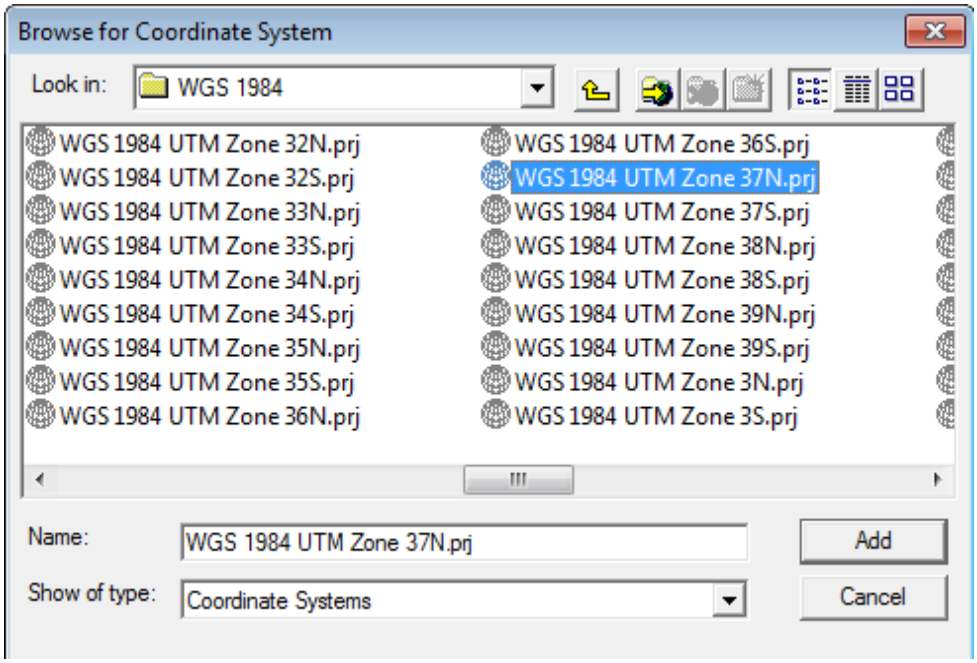
Indicate which is the layer that you want to (re)-project, then click on the hand symbol. A new window will open. Choose “select” from this.



Now you can select either a geographic system or a projected system. If you choose geographical coordinates, choose the world folder and then select WGS84



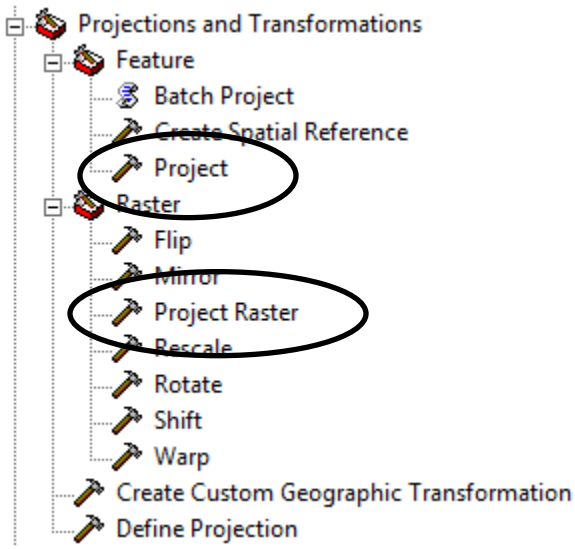
If you want to project your data, choose the projected coordinate system file. Choose UTM then WGS84, then choose the 37N zone



If your data already has a defined coordinate system, then you need to change the projection. Raster and shapefile have two separate tool in the toolbox to change projection.

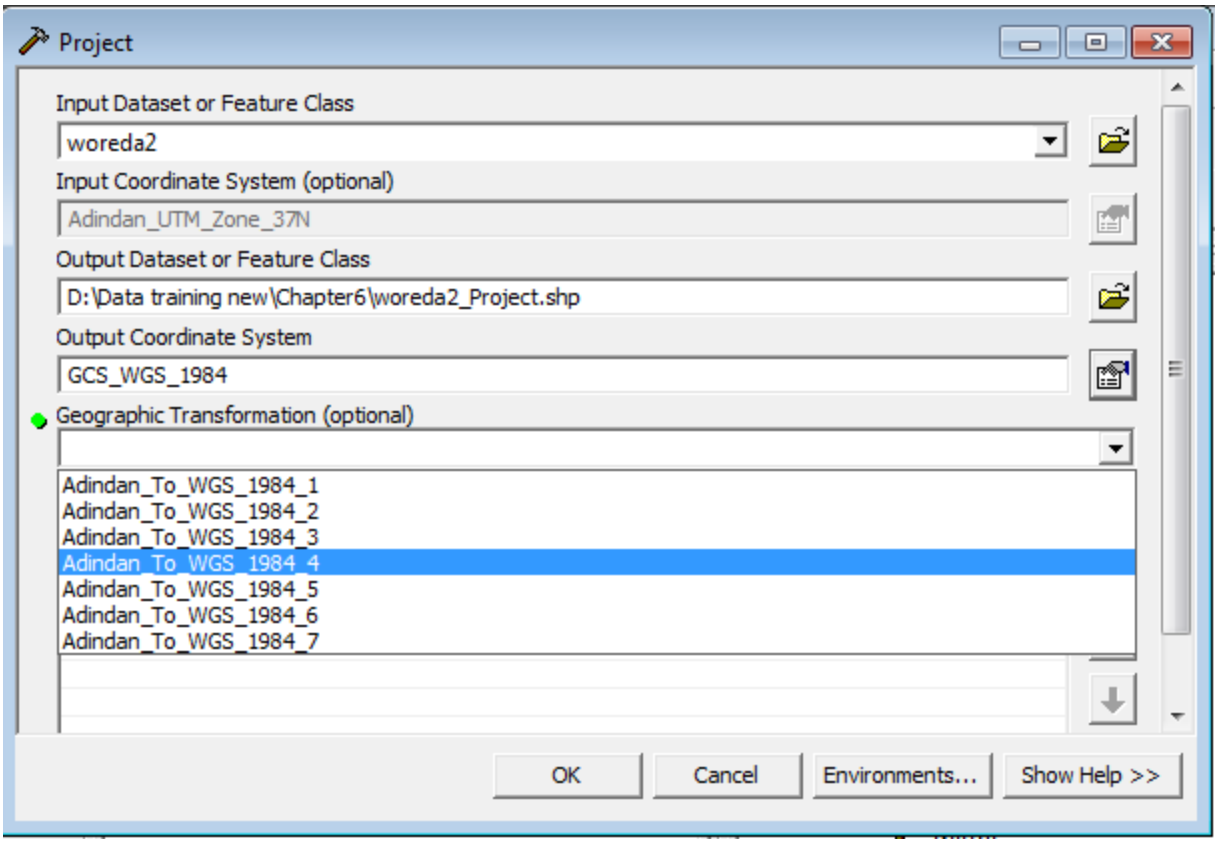
Go to data management → projection and transformation → feature → project for shapefile

Go to data management → projection and transformation → raster → raster project for raster data



If your data is in the right datum but not in the right projection, for example you have the WGS84 (geographic coordinate system) and you want to pass into UTM_WGS84 (projected coordinate system) you can apply the projecting tool as such, without any transformation.

If you need to change the datum, that is you wish for example to pass from the Adindan coordinate system to WGS you need to apply a transformation. For Ethiopia use transformation number 4. As shown below :



Exercise 6-1

1. *Start a new project. Load the woreda2 shapefile and woreda shapefile.*
2. *What happens? What does ArcGIS tell you?*
3. *In what coordinate system is the woreda shapefile? (hint go to "Properties" and "Source")*
4. *What is the coordinate system of the woreda2 shapefile?*
5. *Zoom in as much as possible, do the boarder match?What happens if you use the wrong coordinate system?*
6. *Transform the projection for Woreda2 into the same coordinate system as the town_amahra shapefile. Do the borders match?*
7. *Can you explain the difference between a projected and unprotected map?*

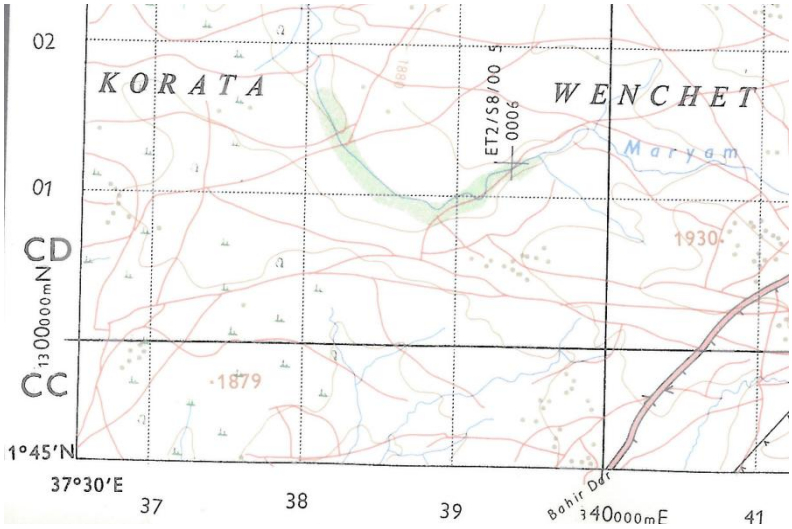
6.5 * Georeferencing

Georeferencing uses map coordinates to assign a spatial location to map features. All the elements in a map layer have a specific geographic location and extent that enables them to be located on or near the earth's surface.

There are different techniques to georeference a raster dataset (scanned maps, aerial photographs or satellite images). In this section we will examine two of the techniques. The first one is georeferencing using control points and the second technique is georeferencing using a referenced scanned map. The second method is referred to as image to map registration.

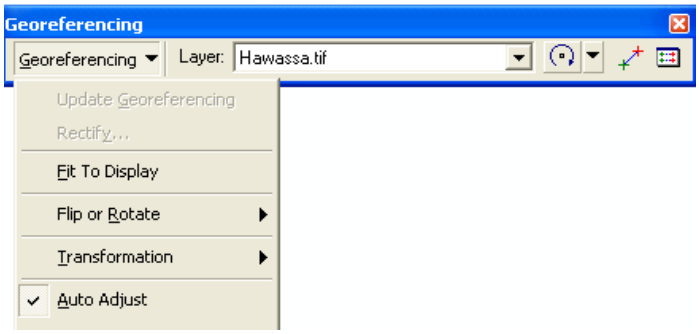
6.5.1 *Georeferencing a raster image using control points

This method uses control points collected from field observations (GPS) or points which already exist on a scanned map (for example when the hard copy map has a visible coordinate system).



- Start a new project in Arc Map
- Set the data frame coordinate system
    - view menu → Data Frame properties → Coordinate Sytem tab
    - Set the coordinate system for your data (i.e the coordinate system you want for your final output)
- Load the data you want to georeference (in this case the scanned map)
- Check the map unit :
    - view menu → Data Frame properties → General tab
- Enter the control points:
    - Tools → customize and check mark the check box Georeferencing
    - From the Georeferencing toolbar verify that the layer is the scanned map you added

- From the georeferencing menu verify that the "Auto Adjust" option is checked. If "Auto Adjust" is active the raster image will be automatically transformed.

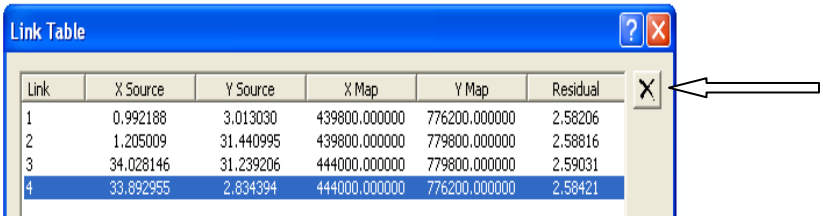


- Zoom to the lower left corner of the scanned map and Click the add control points data button ( ) and click the map corner.

- Right click and enter the X and Y coordinate value
- Fit the map on the screen: click full extent
- Repeat this procedure for the remaining map corners.
- Check the transformation:

  Click the view Link table and check the total root mean square error (RMSE)

  Note that the total RMS error should be smaller than 1.0. If the RMSE is greater than 1.0 you can repeat the georeferencing by selecting "Georeferencing" and "Delete control points" or delete one or more control points by selecting the control points from link table window and click the delete button.



- Click "Georeferencing" and "Update Georeferencing" to save the transformation information with the raster dataset. This creates a new file with the same name as the raster dataset but with an .aux.xml file extension. It also creates a world file for some of the file formats, including .tif and .img files.

*Exercise 6-2

1. *In a new project load the scanned topographic map "woreda.tiff". What do you have to do before loading the data?*
2. *How does ArcMap read the coordinate system of the data? Check the map units. What is the coordinate system of the data?*
3. *With the georeferencing tool, georeference the topographic map by choosing control points*.

6.5.2 *Georeferencing a raster image using a referenced map

This geo-referencing method uses a data set with already defined coordinate value in order to georeference raster images. The steps are almost the same as the previous method:

- Load the referenced data first so that the coordinate system is directly defined
- Zoom to layer
- From the "Georeferencing" toolbar, click the "Layer" drop-down arrow and click the raster layer you want to georeference.
- Click "Georeferencing" and "Fit To Display". This will display the raster dataset in the same area as the target layers. You can also use the "Shift" and "Rotate" tools to move the raster dataset as needed.
- Click the "Add Control Points" tool to add control points.
- To add a link, click a known location on the raster dataset and click a known location on the data in map coordinates (the referenced data). You can look for road intersections, land features, building corners, or other identifiable objects and match them in your raster dataset and aligned datasets.
- Add enough links for the type of transformation.
- You need a minimum of 3 links for a spline or first-order polynomial, 6 links for a second-order polynomial, and 10 links for a third-order polynomial. View "Link Table" to evaluate the transformation.
- You can examine the residual error for each link and the RMS error. If you are satisfied with the registration, you can stop entering links.
- Click "Update Georeferencing"

*Exercise 6-3

1. *In a new project load the file "Ethiopia.jpg" and the woreda file (make sure that you use woreda file and not woreda2)*
2. *Do the two files match? If not, why not?*
3. *How does ArcMap read the coordinate system? Do you observe any difference from the previous exercise? If so what? What is the coordinate system of each of the files?*
4. *With the georeferencing tool, georeference the image by choosing 2 control points.*
5. *Add some more 2 control points. How does it change the georeferencing.*

7 Spatial Data Visualization

During the previous exercises you have used many of the tools ArcGIS offers to work with both geographic and attribute data. In this chapter we will explore how to use the ArcGIS tools to visualize spatial data.

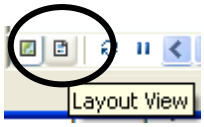
7.1 *Working with a layout view*

A page layout (often referred to simply as a "layout") is a collection of map elements laid out and organized on a page, designed for map printing. Common map elements that are arranged in the layout include one or more data frames (each containing an ordered set of map layers), a scale bar, north arrow, map title, descriptive text, and a symbol legend.

The "Layout view" is where you add map frames, graticules, and other finishing touches to the map. What you see on the layout is what you get if you print or export the map to the same page size.

In ArcMap, one can work in either "Data" or "Layout" views. Data views are single frames, used mainly to explore or edit data. The layout views, on the other hand, are used to display and print maps, and can contain many frames. However, it is also possible to edit the data in layout views if required. Most tools and options available in the data view are also available in the layout view

To switch to the layout view: view menu → layout view

Or click on the layout button on bottom bar: 

The layout toolbar will appear  and the display changes to show the page layout with rulers along the sides. The map in the layout view is directly linked to the map in the data view. Therefore, if you zoom in or out in your current map in the data view, the same will happen in your layout view.

In addition, there are rulers, guides, and grids to help you arrange map elements on the page. These can be found by right-clicking on an empty portion of the map layout and selecting from the context menu that appears. In addition, you may align, nudge, distribute, rotate, and resize selected elements to place them where you wish. The map background color may be changed by selecting the data frame and clicking the down arrow next to the Fill Color button on the Draw Toolbar. When you select a desired color, the map background color will be updated.

7.2 *Labeling the features*

You can have features within the map display labeled. You can do this by right-clicking on the LAYER of interest in the table of contents (NOTE: click on the layer name and NOT the symbol) and selecting the "Label Features" option. The "label" field will be labeled. You can change it by double clicking on the layer → properties→ labels → label field.

If you want to move the label names around, you need to use "Convert labels to annotations": right click on the layer → convert labels to annotations → choose in this map.

Note that once you have changed labels to annotations, they become independent text that you can change and format, but it is not linked to your database anymore.

7.3 *Adding a title, legend and scale bar*

Map title

A map title may be added to the layout by clicking the "Insert" menu and selecting the "Title" option. A text box will be added to the page. Within this text box, a default title will be present. You can type in a preferred title within the text box and press "Enter". You can then go back and edit the title by double-clicking on the title and editing its text properties. The font, size, style, or color of the title may be changed using the "Draw" Toolbar.

North Arrow

A North Arrow may be added by clicking the "Insert" menu and selecting the "North Arrow" option. In the "North Arrow Selector" dialog box that appears, you may select from a variety of north arrows and change the properties of any selected arrow.

Once an arrow has been selected, its properties specified, and the OK button clicked, the north arrow will be added to the map layout. You can resize the north arrow by clicking and dragging on one of its corners. In addition, you can move the north arrow to any desired location within the map layout.

Scale

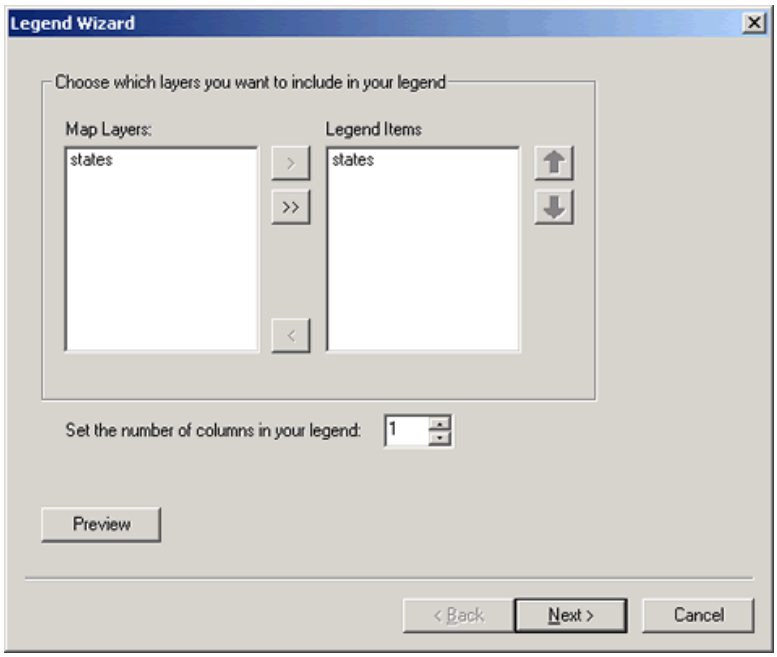
The scale of a map is the ratio between distances on the map and the real world. The scale is a fractional number which is indicated as 1 to some larger number, where the larger number is the denominator of the fraction. For example a 1:24,000 scale map shows features at 1/24,000th of their actual size. The terms small scale and large scale can be used to describe the amount of detail on the map as well as the area extent of the map. Since scales are actually fractions a 1:24,000 scale map is a larger scale map than a 1:250,000 scale map. Smaller scale maps show a larger area with less detail while larger scale maps show small areas at greater detail.

For hardcopy maps, the scale is a fixed property of the map which can be used to determine the distance between features. The scale of digital data is actually a measurement of precision of the data since the data can be drawn (on a monitor or a printed map) at a wide range of Scale is an important consideration when working with digital data as computers make it possible to compare and analyze data at a wide variety of scales. Differences in scale between datasets can introduce error in spatial analysis and lead to incorrect or misleading results

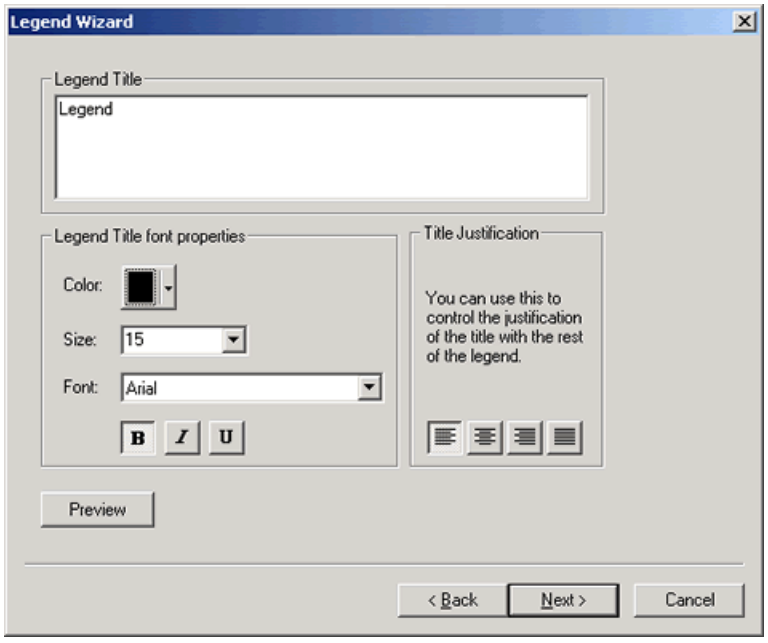
A Scale Bar may be added by clicking the “Insert” menu and selecting the “Scale Bar” option. The desired scale bar style may be chosen and its properties edited within the “Scale Bar Selector” dialog box. When the OK button has been clicked, the chosen scale bar will automatically appear within the map layout. You can click and drag the scale bar to the desired location.

Legend

The legend describes the data included within the map. A Legend may be added by clicking the “Insert” menu and selecting the “Legend” option. The “Legend Wizard” dialog box will appear.

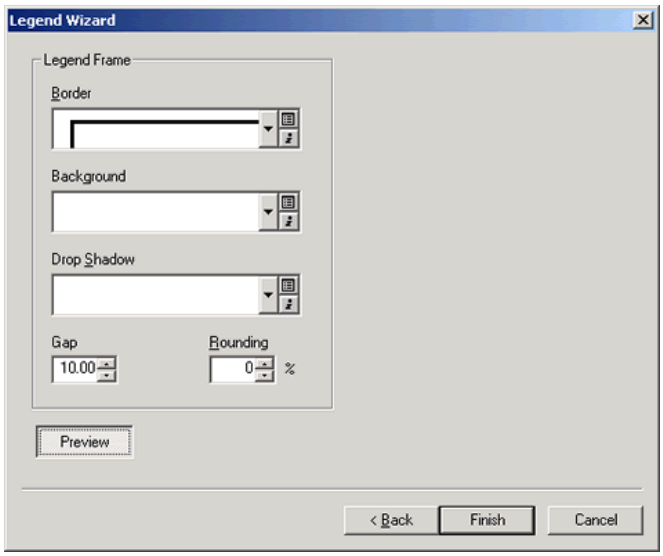


By default, the legend includes all layers from the map, and the number of legend columns is set to one. You can choose which layers you wish to be displayed in the legend by selecting the layer from the "Map Layer" box and clicking the right arrow ">>". The selected layers will be displayed in the "Legend Items" box. Once you select the layers you want, click the "Next" button. The second frame of the wizard will appear.

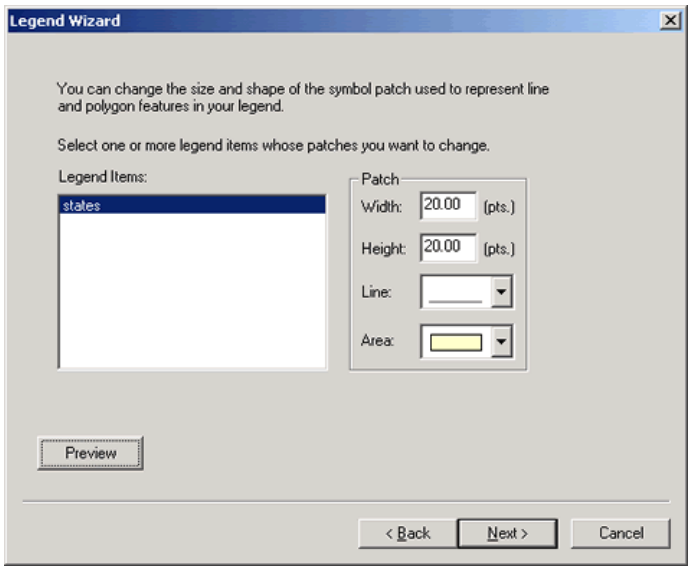


Within this frame, enter a legend title, specify its properties, and set the title justification. Once the parameters are set click the "Preview" button in order to see a sample legend displayed on the

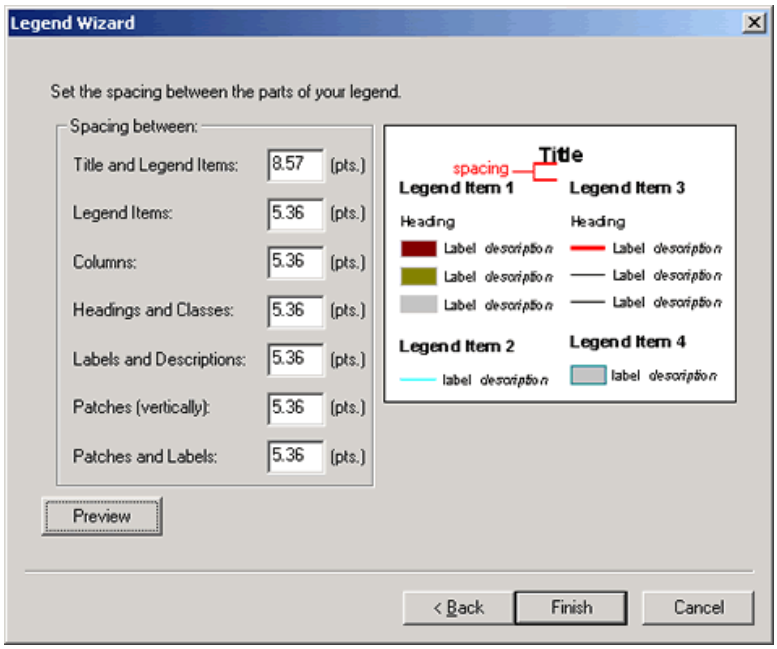
map. Click the “Preview” button again before you can move on to the next frame of the legend wizard dialog. When all parameters have been selected, click the “Next” button. The next frame of the wizard will appear.



Within this frame, you may select a border for the legend, background color, and drop shadow. Once parameters are selected, click the “Next” button. The next frame of the wizard will appear.



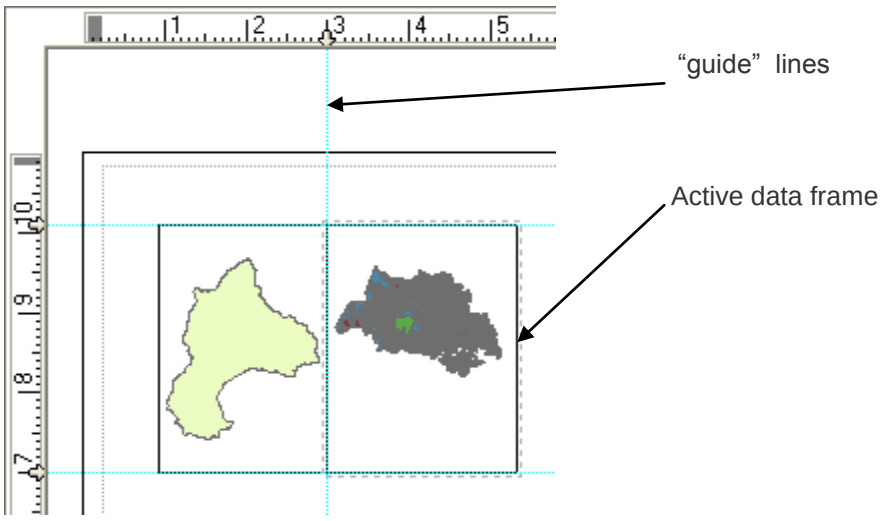
Within this frame, you may change the size and shape of the symbol patch used to represent line and polygon features within the legend. Once parameters have been set, click the “Next” button. The last frame of the wizard will appear.



Within this frame, you may change the spacing between the different components of the legend. Once the spacing has been set, click the “Finish” button. The layout display will updated, and you can re-size and move the legend box to a desired location.

7.4 *Working with different data frames*

Different maps can be shown on the same page by adding a new data frame: menu insert → add data frame. You can select each data frame and move it around. When you click on the rules you get blue “guide” lines that can help you to shift, and format the data frame.



If you switch to data view, then only the active data frame (the frame with the ------- lines) will be shown. You can switch to the other frame in the layout view by clicking on the frame you want to work with.

Exercise 7-1

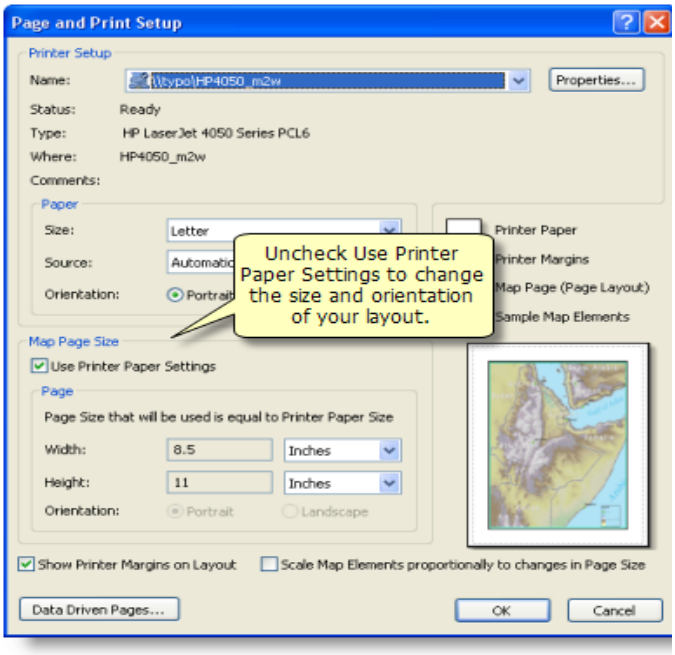
1. *Display the Tana woredas (tanaworeda shapefile created in a previous exercise) giving a different color to each woreda. Add another data frame that shows Ethiopia and highlights the selected woredas.*
2. *Add a North arrow, a legend and a scale bar*
3. *Label the woredas and make sure that each woreda is labeled in a clear and distinct way.*
4. *What are the criterias to make your map readable?*
5. ** Link the two data frames so that when you move one map, the other also adjusts automatically? Can you create a map that shows the extent of one data frame within another data frame (Hint look in frame properties – extent indicator)*

7.5 *Setting the page size of your map layout*

Since a layout is the arrangement of map elements of various types on a page for the purpose of printing or exporting, one of the obvious initial steps in building your layout is to set the desired page size using the “Page and Print Setup” dialog box. By default, when you create a new map in ArcMap and choose “Blank Map”, the layout page dimensions are set to your default printer's page size.

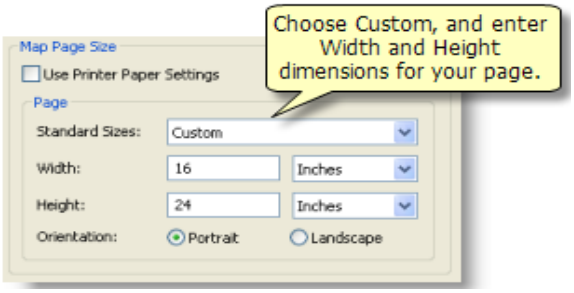
Setting the page size for a layout

- Click File → Page and Print Setup on the main menu to open the Page and Print Setup dialog box.
- You can set your layout page size as shown below

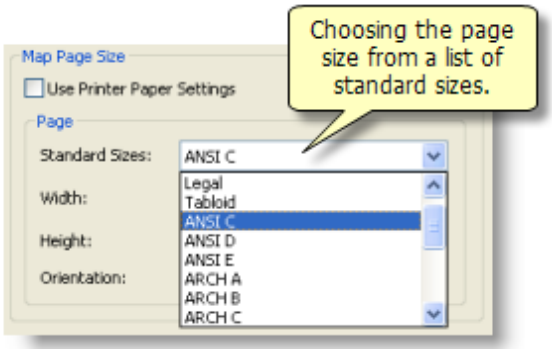


By default, the page size of your layout for a blank map will be set to the printer's paper size (for example, 8.5 by 11 inches).

- To set your own page size, uncheck the “Use Printer Paper Settings” box to set the page size of your layout. If you uncheck this option, you can choose any page dimensions you want, but the printer name will not be saved with the map document (.mxd).
- Set the page size by typing the preferred page dimensions into the “Width” and “Height” boxes.

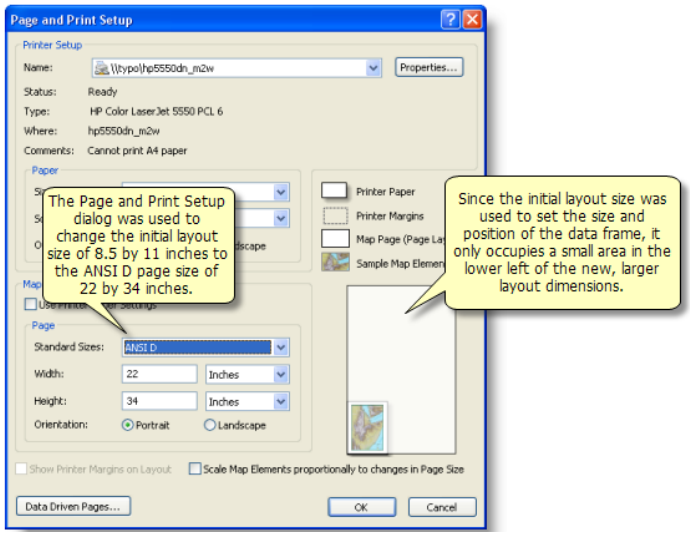


Alternatively, you can select a standard page size from the “Standard Sizes” drop-down list, such as ANSI C, Architectural D, or ISO A2.

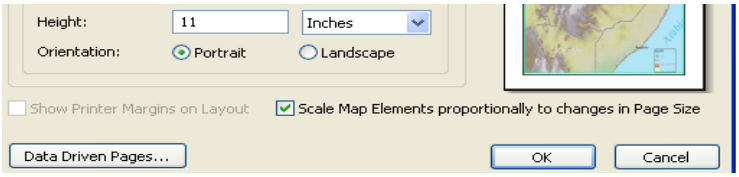


- Once you change your layout's page size, you will need to resize and reposition all the map elements to fit the new page dimensions.

Map Page Size is linked to the Paper Size of the current printer whenever the Use Printer Paper Settings checkbox is checked. The default printer paper size used by ArcMap is 8.5 x 11 inches. In the example below, the Map Page Size has been unlinked from the original 8.5 x 11 size and set to a larger page, 22 x 34. The initial data frame was placed on the layout based on the original, smaller, page size. So, after changing the Map Page Size, you need to use the layout view in ArcMap to rearrange your layout. Reposition the data frame and layout elements so that they will work well with the new page size.



Or you can tick “Scale Map elements proportionally to changes in page size”

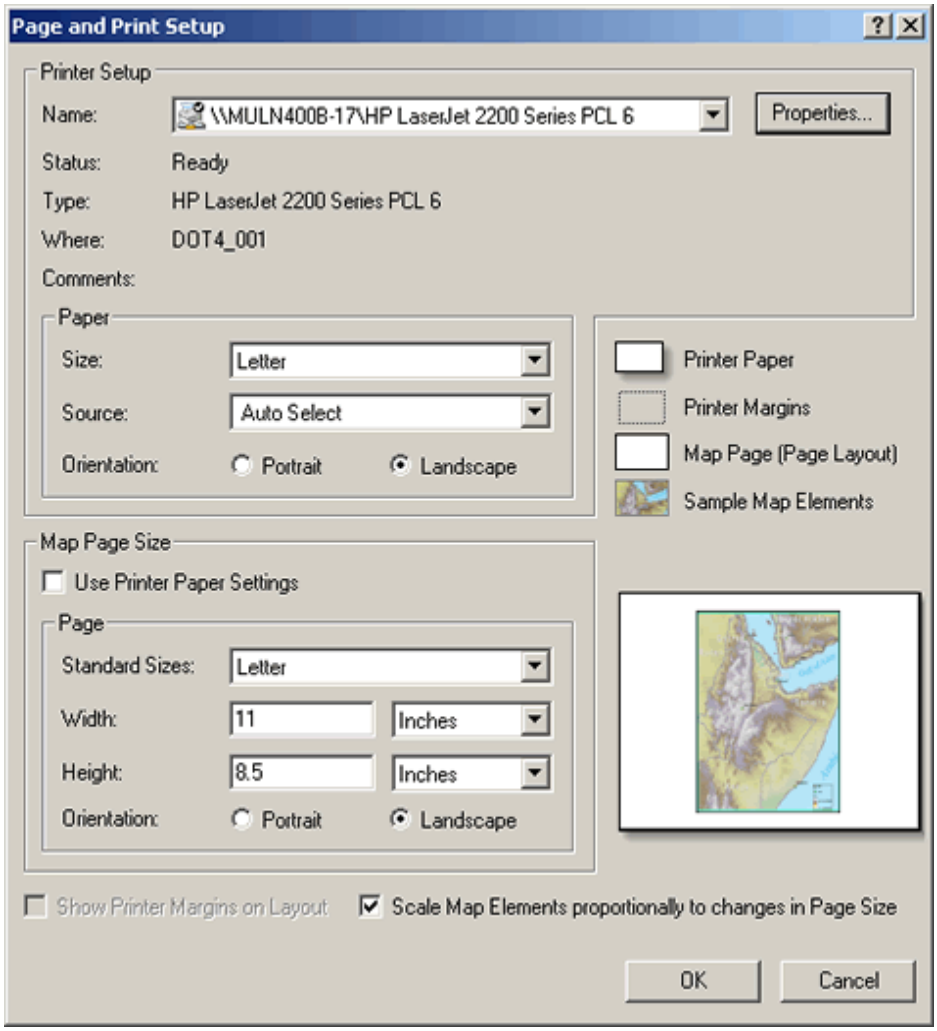


7.6 *Printing and exporting your map*

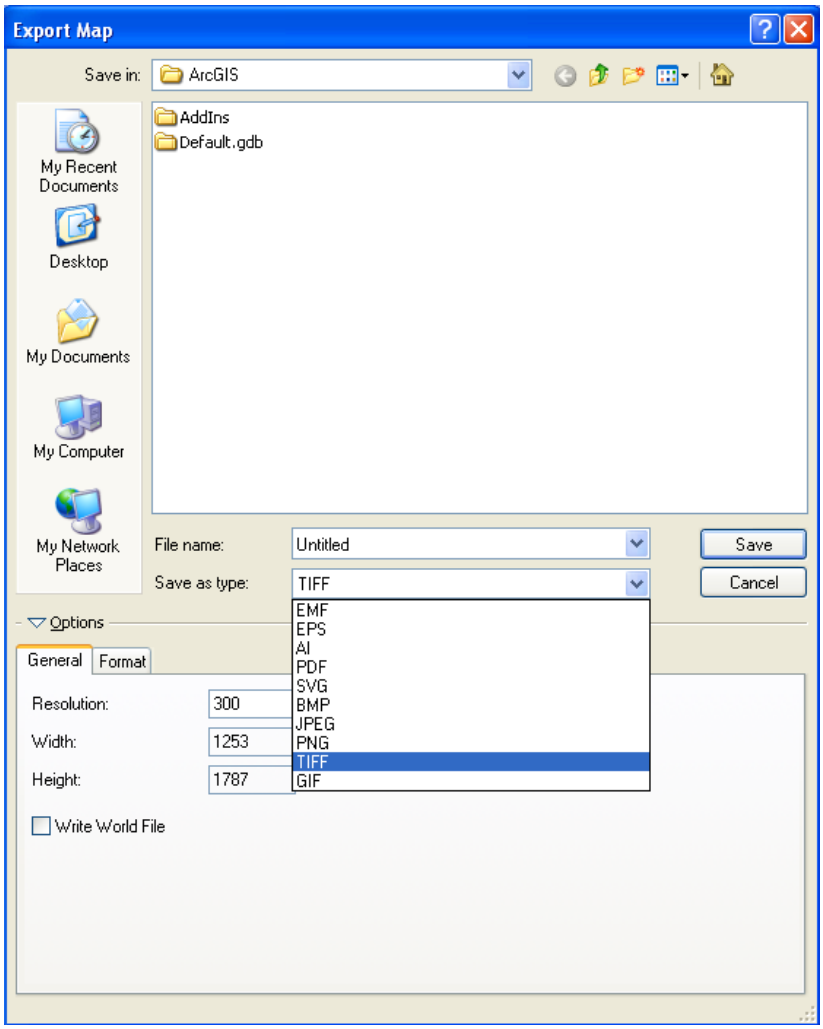
Before printing the map, you should always preview it. This can be done by clicking the “File” menu and selecting “Print Preview”. This allows you to see if anything needs to be changed before the map is printed.

If changes need to be made, the “Print Preview” should be closed (by clicking the “Close” button), and the appropriate changes made. If everything appears the way that it should, you may click the “Print” button. Appropriate print parameters must be set, and the OK button should be clicked when you are ready to print the map.

For setting your printing settings, right-click anywhere on the layout background (outside the map frame) and choose “Page and Print Setup” from the drop-down menu. (You can also access Page Setup and Print Setup from the File menu).



You can also save your map as an image (tiff, jpeg, etc): in the menu file → export map → indicate where you want to save it in which format you want to save it.



For publication, you need high resolution maps. Do this by saving your map as tiff file and 300dpi. The file size will be very large, so for other uses you can select JPEG and 100dpi.

Exercise

1. *Export your map you have created in the previous exercise as a tiff file with 300dpi.*
2. **Set the right printer setting and preview the maps.*

8 Spatial Data Analysis

Spatial Analysis is the study of geographic features and the relationships between them, and involves the the process of extracting or creating new information about a set of geographic features. Spatial analysis involves data queries performed on georeferenced information to answer complex questions such as:

- How many people live within one mile of a hazardous waste site?

- How far is it between two places? (measuring distances)
- Where is land zoned for industrial use?
- Where are all the sites suitable for building new houses (or new healthcare facilities)?
- How many houses lie within 100m of this water main?
- What is the total number of patients within 10 km of this healthcare facility?

Spatial analysis works on both vector and raster data. In ArcGIS, different vector and raster operations can be carried out in ArcToolbox.

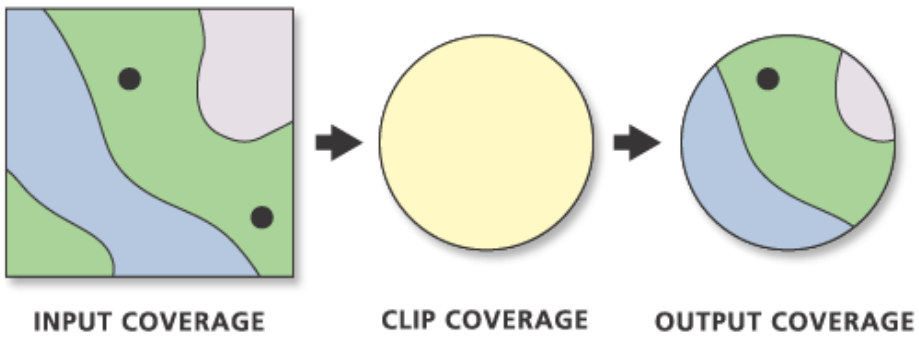
8.1 *Spatial analysis of vector data*

8.1.1 Clip

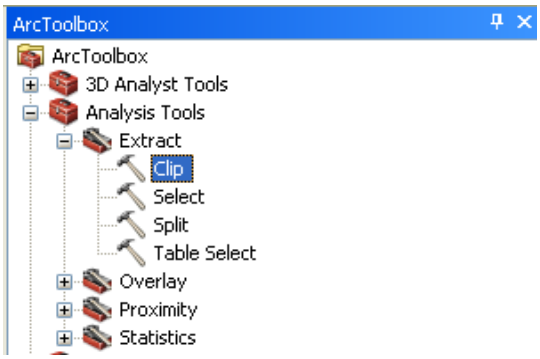
Clip is used when we want to cut out a piece of one layer using one or more of the polygons in another layer in order to work with only the data for an area of interest. For example when you work within a given study area, data that is external to the boundary of the study area can be removed with the clip function.

The layer that will have its features clipped can contain points, lines, or polygons. If we only want a subset of the features in this layer to be clipped we can select them using any of ArcMap's feature selection tools, before we start the "Geoprocessing Wizard". The layer on which the clip will be based must contain polygon features. If we only want a subset of the polygons in this layer to be used to perform the clip,' they need to be selected before starting the "Geoprocessing Wizard.

The attributes of the features in the output layer will be the same as those of the feature in the layer being clipped. The output from this Geoprocessing operation will be in the same coordinate system as the data frame, irrespective of the coordinate system of the data. (Exception: when saving the output from this operation as a feature class in an existing feature dataset).

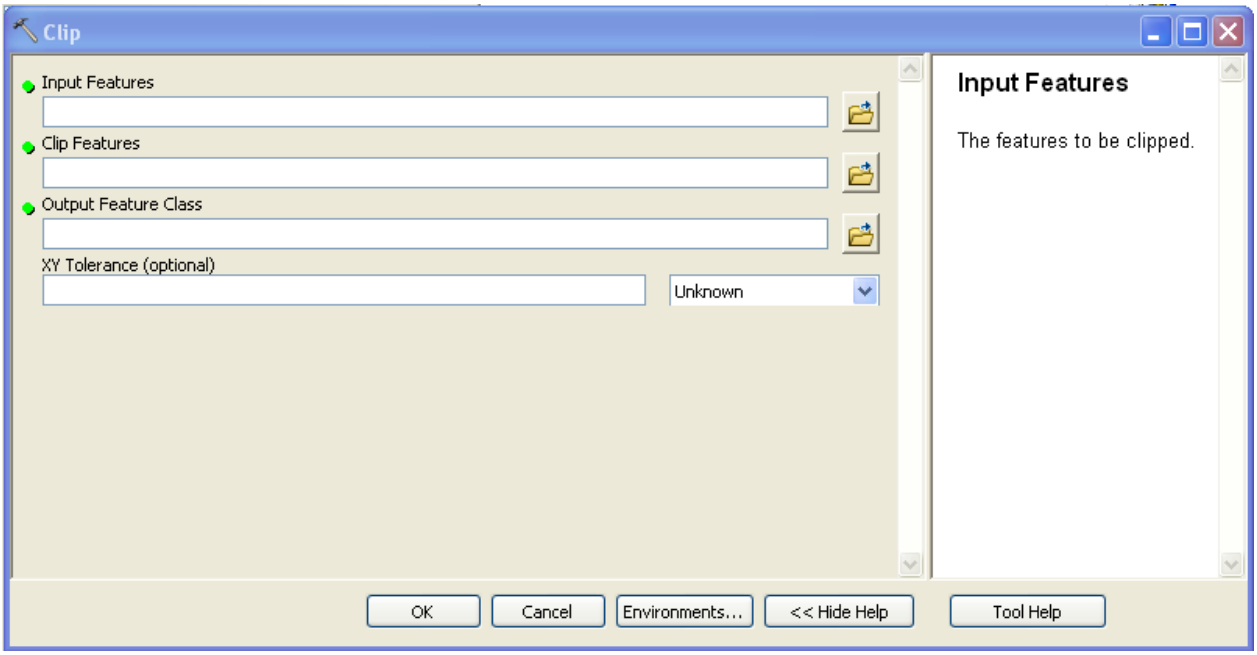


To clip, make sure that you have the "Toolbox" window open. In the Toolbox → analysis tool → Extract → clip



Once you have done this:

- open the clip window
- under “Input Feature” select the map to be clipped
- under “Clip Feature” select the map that will be used to perform the clip
- under “Output Feature” indicate where to save the new layer and give it a name



Exercise 8-1

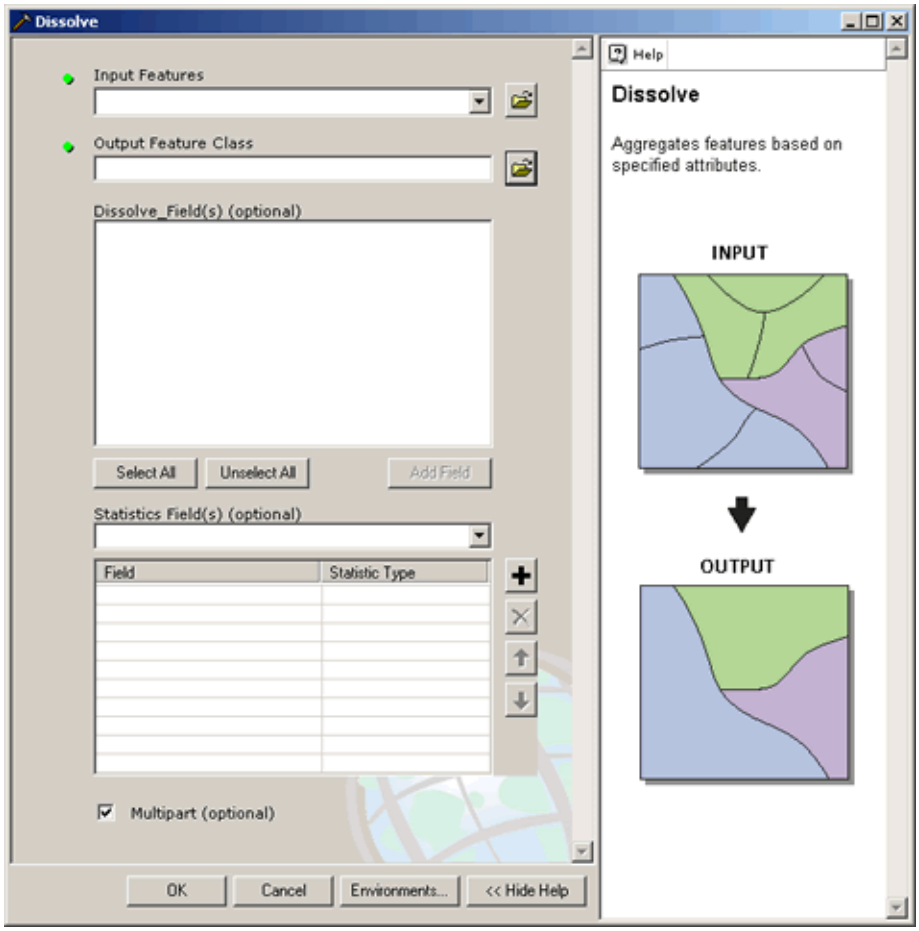
1. *Clip the woredas that are part of the Tana basin (you created the Tana basin map in chapter 6.1)*

8.1.2 Dissolving features

Dissolve is another tool used to trim away unnecessary detail that is not relevant to the scope of the project. Data can be simplified by dissolving several features in a layer into one. We use Dissolve when we want to aggregate features based on a specified attribute.

The output from this Geoprocessing operation will be in the same coordinate system as the data frame, irrespective of the coordinate system of the input layer's data source (exception: when saving the output from this operation as a feature class in an existing feature dataset).

To dissolve multiple features into one, click the ArcToolbox Data Management Tools → Generalization → Dissolve. The Dissolve tool dialog box opens.



In the "Dissolve" dialog box, select the "Input Features" from the drop-down menu or browse to the feature. After specifying a name and location for the "Output Feature Class", move to the "Dissolve_Field(s)" option. From the list of attributes select one or more on which to dissolve. Once selected, click the "OK" button. The output is automatically added to the map display.

Exercise 8-2

1. *Based on the woreda file create a map of regions using the dissolve option.*
2. *Note that Zone 03 stands for Amhara, export Amhara into a new layer and*

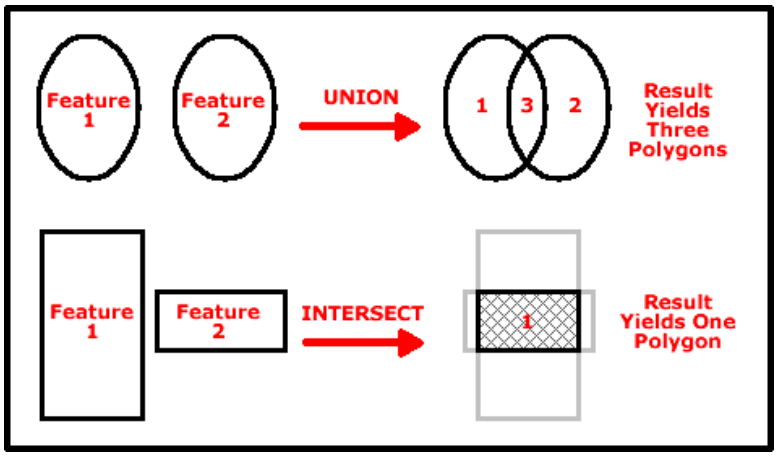
8.1.3 Overlaying data

An overlay operation is also one of the most common spatial analysis tools. Overlays allow you to identify areas where features in two layers overlap. A new data set may be created based on these overlaps.

8.1.3.1 *Union overlay*

We use Union when we want to overlay two polygon layers so that the resulting output layer a) has the combined attribute data of the polygons in the two inputs, and b) contains all the polygons from the inputs, whether or not they overlap. In this way, we can produce a new layer combining the features and attributes of two polygon layers.

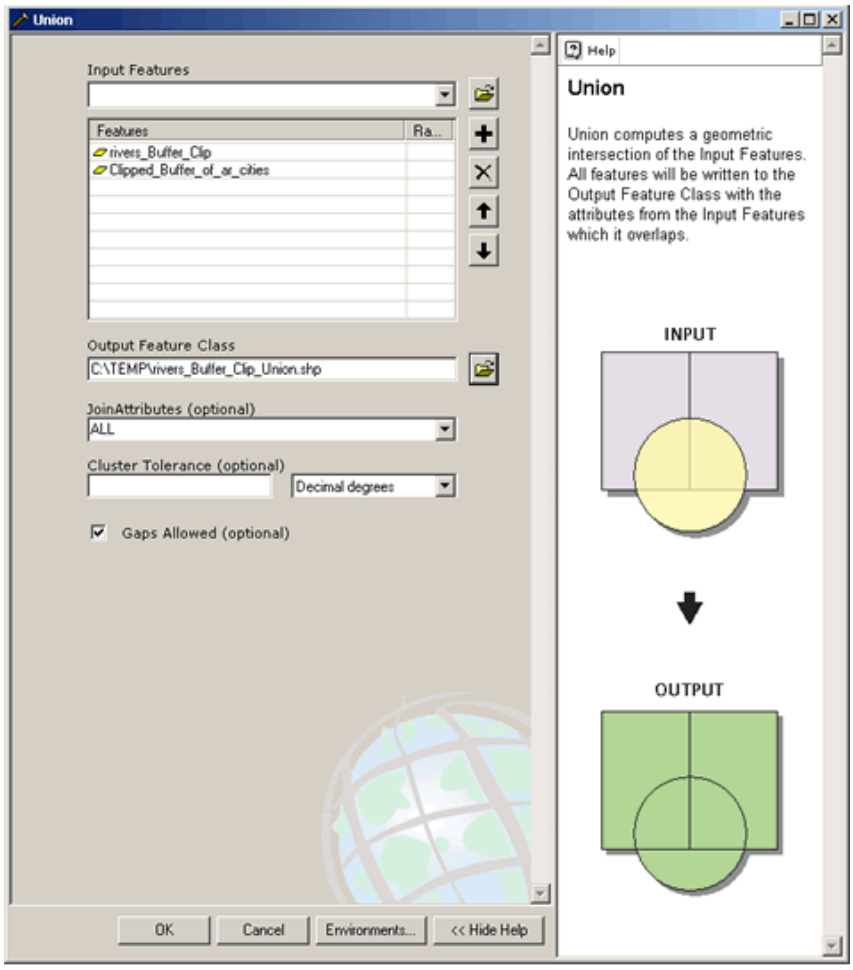
The output from this Geoprocessing operation will be in the same coordinate system as the data frame, irrespective of the coordinate system of the data source of the input layers (exception: when saving the output from this operation as a feature class in an existing feature data set).



Union Overlay:

The union overlay option is useful if you wish to combine multiple data layers into a single layer. For example, if you do not wish to build a house within close proximity to a stream or a railroad, you could create a buffer area that represents proximity to a stream. You could do the same for the railroad layer. Last, you could union the two buffers. The final result would represent all areas in which you do NOT wish to build a house.

To perform a union overlay, go to ArcToolbox's “Analysis Tools”, select “Overlay”, and then click “Union”. Specify the input layers to the union and a name for the output data set.



Once you click *OK*, the result will be added to the ArcMap display if Arc Toolbox was used through ArcMap.

Exercise 8-3

1. *Make a union with laketana shapefile and woreda shapefile.*
2. *Open the attribute table of union. What can you see?*
3. *Can you color Lake Tana in blue? Compare with exercise 3-2*

8.1.3.2 *Intersect Overlay:*

We use intersect when we want to overlay a layer with the polygons in another layer so that the resulting output layer a) has the combined attribute data of the features from the two inputs, and b) only contains features that fall within the spatial extent of the overlay polygons. In this way, we can find those features

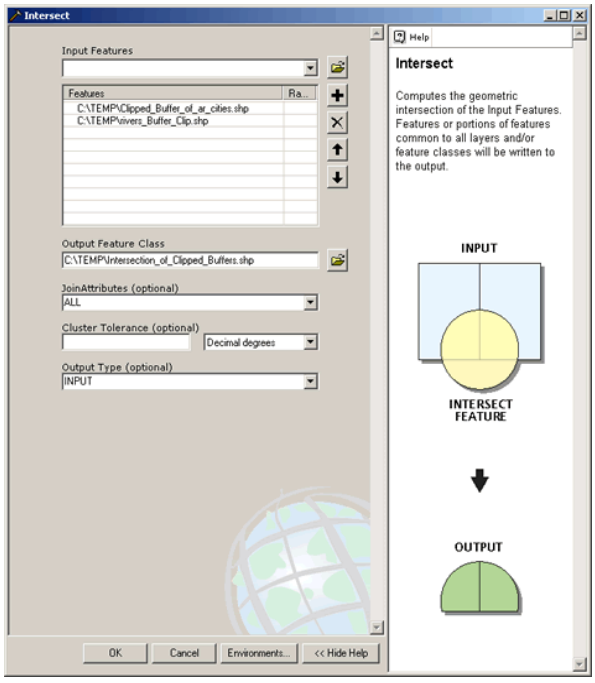
that overlap and ‘stamp’ the attributes of the overlay polygons in the second layer onto the features in the first layer.

We can intersect polygons with polygons and lines with polygons. We can specify that the intersection be limited to the currently selected set of features in either or both of the two inputs. If we only want a subset of the features in either or both layers to be used in the process, we can select these features using any of ArcMap’s feature selection tools.

The output from this Geoprocessing operation will be in the same coordinate system as the data frame, irrespective of the coordinate system of the input layer’s data source (exception: when saving the output from this operation as a feature class in an existing feature dataset).

In the above union overlay example, the output shows where at least one of the buffer criteria have been met. A more restrictive overlay is to find the places where BOTH criteria occur in the same place. This is otherwise known as the Boolean AND operation.

To perform an intersect overlay, go to “Analysis Tools” in ArcToolbox and click on “Overlay”. From the list of Overlay tools double-click on Intersect. You are prompted to select the input features for intersection and the output feature class.



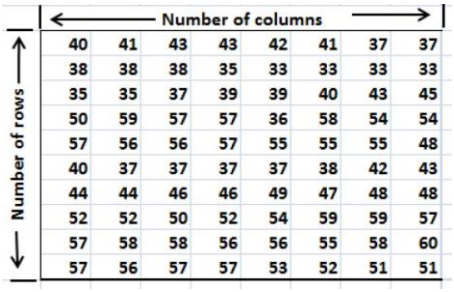
Click the OK button. The result is automatically displayed in ArcMap.

Exercise 8-4

1. **Intercept the Lake Tana basin with the Tana woredas.*
2. **Open the attribute table of result. What can you see?*
3. **Compare the results from the union and intercept operations. What is the difference between the two?*

8.2 **Spatial data analysis with raster data*

In this section we present an introductory concept to the raster data structure. Understanding of the raster data structure, in comparison to what you have learned in the previous modules about vector data set will help you to decide when phenomena should be represented as raster rather than vector data set. Raster data (an image or a grid) consists of columns and rows. The rows are numbered starting from the upper left corner of the image, with each cell value in the image representing information about the target and identified by the corresponding column number and row number. For example, in the figure below the cell value 36 corresponds to the cell in the column 5 and row 4.



8.2.1 * Raster data types

In ArcGIS the fundamental unit of analysis in raster data is the “Cell”. A cell represents a location in space. The condition of a given cell is recorded as a numeric value for each cell. As described above a raster is a regular arrangement of cells. The process of choosing a size for these cells and assigning values to them is called sampling. There are two types of rasters: integer rasters, in which the attribute for each cell is an integer (a value without a decimal point) and floating point (decimal) rasters. In addition to integers and floating point numbers, cells may also have a value of “NoData” or “Null”. Nodata cells affect map algebra functions in various ways.

In an integer-based raster, each unique cell value is associated with a row in a “Value Attribute Table”. Each cell sharing the same value (e.g. 24: Forest) is associated with every other cell having the same value in that layer. These related areas of cells (which need not be continuous) is known as a “Zone”. If we want to calculate a summary of the data such as the average of the values in the layer we could use a procedure known as a “Zonal Function” to find the average value that occurs within a particular zone.

*Exercise

1. *Load the elevation raster layer “dem_eth”. What type of raster is it?
2. *What is the coordinate system?
3. *What is cell size and how many columns and rows does the image have?
4. *What are the minimum and maximum values?
5. *Choose a Color ramp of brown to white symbolizing elevation.
6. *Which part of the Ethiopia has higher elevation values?
7. *What is the grid size? What are the implications of the grid size on the analysis performed with the digital elevation maps?

8.2.2 * Geoprocessing Environment Settings for Working with Rasters

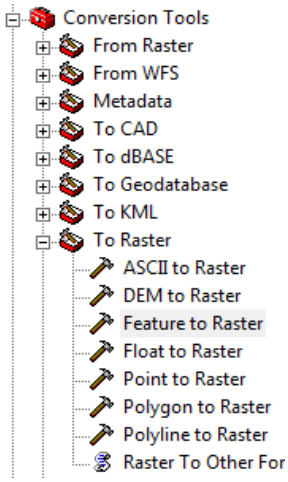
When making models with raster functions you should be sure to set your Analysis Extent to a specific area (defined for example by the extent of one of your input layers).

Go to menu customize → extensions → select spatial analyst

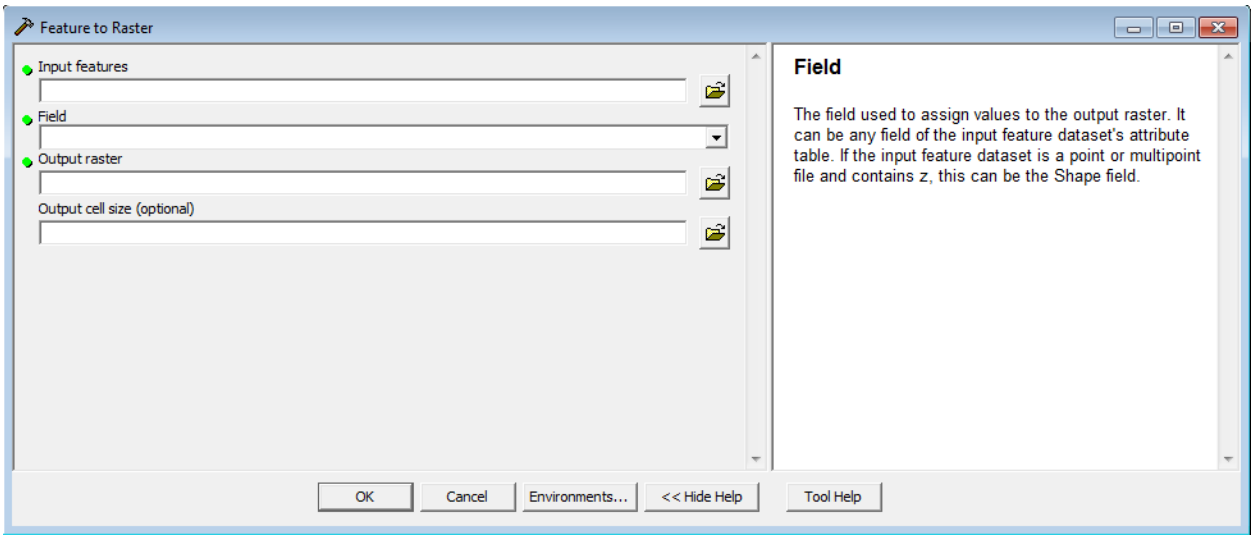
8.2.3 *Basic Raster Transformations and Associations

8.2.3.1 *Feature to Raster*

If some of your data is the form of a shapefile, but you need it in raster, then you can use the “Feature to Raster” tool in the toolbox → conversion tool → to raster



Indicate the file you want to transform into a raster, the field which should be considered for the raster, and the name and location of the new raster file and the output cell size. Choose a cell size that matches other raster data you have.

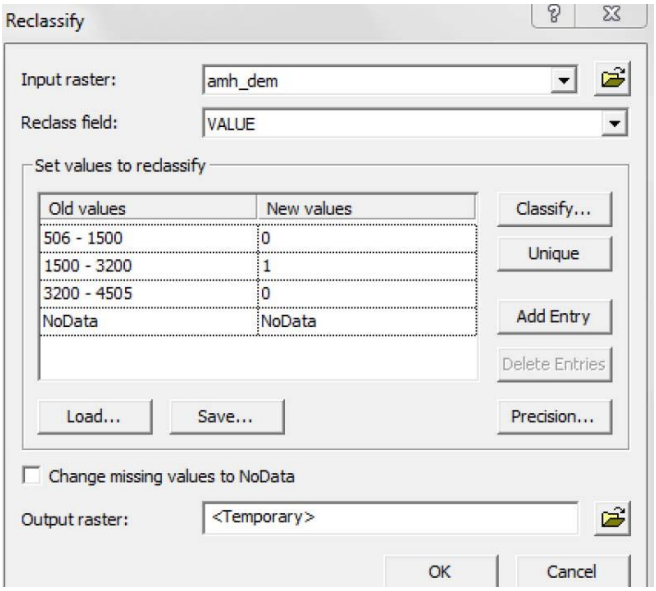


Exercise 8-5

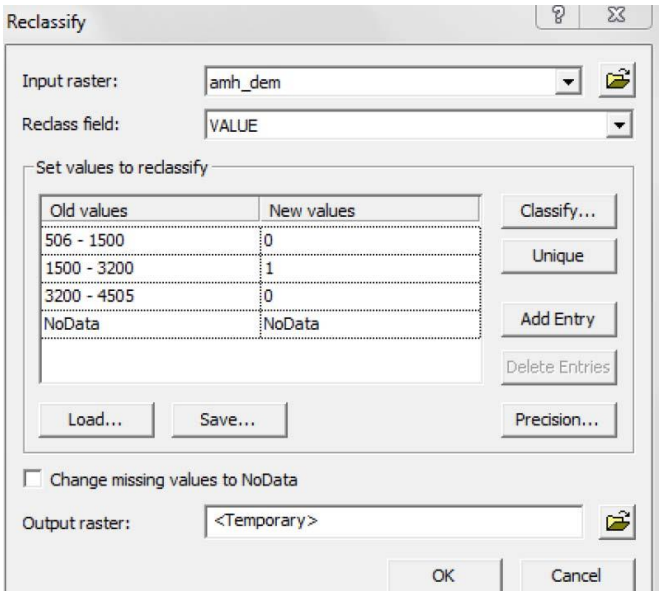
1. **Transform the soil map "Amhara_soil" into a raster containing the major soil types. Create this raster in such a way that you can easily combine it with the elevation map "dem_ethiopia".*

8.2.3.2 **Reclassify*

The reclassify tool permits the reclassification of the values in a layer into a set of classes, for example transform a set of continuous values into three classes, "high", "medium" and low.



The tool can be found in the toolbox → spatial analyst → reclassify



By clicking on “Add Entry” you can indicate which values fall into which class.

*Exercise 8-6

1. **Potatoes may be grown on the following suitable soils: Lithosol, Nitosol and Cambsol. Create a map that shows suitable areas for potatoes in terms of soils using the raster soil map you created in a previous exercise in this chapter (or find it in the intermediate map folder). Give the value 1 to a suitable grid cell and the value 0 to a non suitable cell.*

8.2.3.3 *Clipping rasters*

In order to clip a raster, you need to use a different tool to that used for vector files (shapefiles), namely “Extraction”. This is found in the toolbox → spatial analyst tool → extraction

If you have a shapefile which represents the area you want to extract, you will need to use the tool “Extract by Mask”.

Exercise 8-7

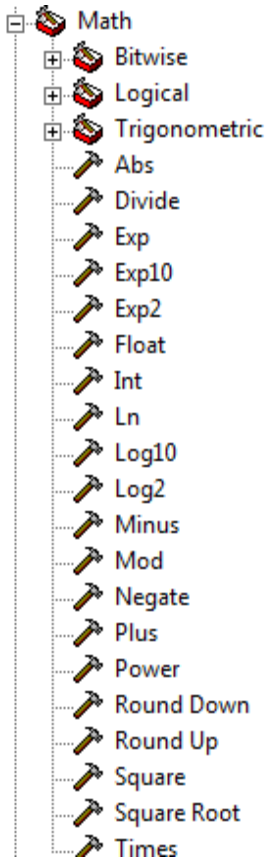
1. *Clip the Amhara region from the elevation map (hint use the Amhara shapefile, if you have not created it in a previous exercises then take it from "intermediate maps" folder).*
2. *Potatoes are suitable for planting on elevations between 1500-3200 masl. Create a suitability map that has value of 1 if the elevation is suitable and a value of 0 if elevation is not suitable.*

8.2.4 *Raster calculation

If every cell in your raster datasets have the same size, it is easy to combine them through mathematical algebra (addition, multiplication…) but also to calculate some predefined function, for example the slope, the direction of water flow etc.

8.2.4.1 *Math algebra*

In the toolbox under "Spatial Analyst" you can find all the mathematical functions that can be easily used to combined data sets:

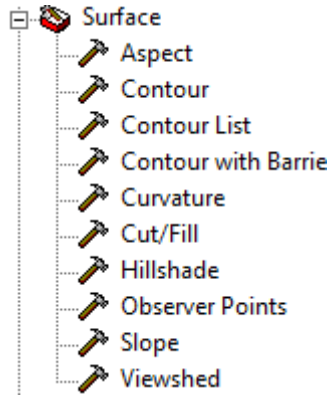


For each of these you need to indicate which raster you want to use to compute your calculation, as well as the name and location of the resulting new raster.

8.2.4.2 **Predefined functions*

ArcGIS also has predefined functions for working with elevation maps. Briefly presented here are two categories of these: “Surface” functions and “Hydrology” functions.

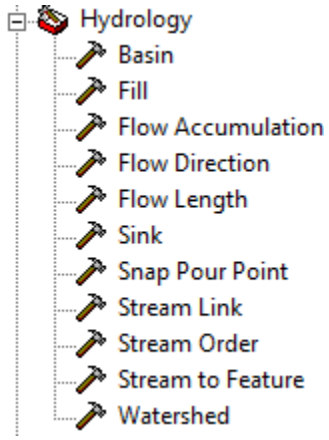
The “Surface” functions can be found in the toolbox under spatial analyst → surface



With the Surface tools, you can gain information by producing a new dataset that identifies a specific pattern within an original dataset. You can derive patterns that were not readily apparent in the original surface, such as contours, angle of slope, steepest downslope direction (Aspect), shaded relief (Hillshade), and Viewshed.

Tool	Description
Aspect	Identifies the direction of maximum rate of change in z-value from each cell.
Contour	Creates a line feature class of contours (isolines) from a surface raster.
Contour List	Creates a line feature class of selected contour values from a surface raster.
Contour with Barriers	Creates a line feature class of contours (isolines) from a raster surface, and allows the inclusion of barrier features.
ContourAsPolyline	Creates a polyline of the contour (isoline) that passes through a specified location. The contour is derived from an input surface raster.
ContoursAsPolylines	Creates a GeometryCollection of contours (isolines) that pass through specified locations. The contours are derived from an input surface raster.
Curvature	Calculates the curvature of a surface at each cell center.
Cut/Fill	Calculates the volume change between two surfaces.
Hillshade	Creates a shaded relief raster from a surface raster by considering the illumination angle and shadows.
Observer Points	Identifies which observer points are visible from each raster surface location.
Slope	Identifies the rate of maximum change in z-value from each cell.
Viewshed	Determines the raster surface locations visible to a set of observer features.
Visibility	Performs visibility analysis on a raster surface by determining how many observation points can be seen from each cell location of the input raster or which cell locations can be seen by each observation point.

The Hydrology function can be found in the toolbox under spatial analyst → hydrology



When analyzing the flow of water, you may want to know where the water came from and where it is going. The following topics explain how to use the hydrologic analysis functions to help model the movement of water across a surface, the concepts and key terms regarding drainage systems and surface processes, how the tools can be used to extract hydrologic information from a digital elevation model (DEM), and sample hydrologic analysis applications.

Tool	Description
Basin	Creates a raster delineating all drainage basins within the Analysis window.
Fill	Fills sinks in a surface raster to remove small imperfections in the data.
Flow Accumulation	Creates a raster of accumulated flow to each cell by accumulating the weight for all cells that flow into each downslope cell.
Flow Direction	Creates a grid of flow direction from each cell to its steepest downslope neighbor.
Flow Length	Calculates upstream or downstream distance along a flow path for each cell.
Sink	Creates a grid identifying all sinks or areas of internal drainage.
Snap Pour Point	Snaps selected pour points to the cell of highest flow accumulation within a specified neighborhood.
SnapPour	Snaps selected pour points to the cell of highest flow accumulation within a specified neighborhood.
Stream Link	Assigns unique values to sections of a raster linear network between intersections.
Stream Order	Assigns a numeric order to segments of a grid representing branches of a linear network.
Stream To Feature	Converts a raster representing a raster linear network to a feature class.
StreamShape	Converts a grid representing a raster linear network to a shapefile.
Watershed	Determines the contributing area above a set of cells in a grid.

*Exercise 8-8

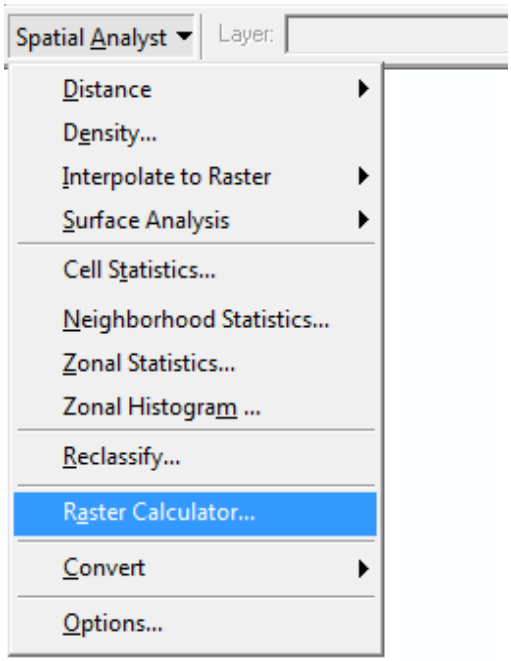
1. **From the elevation map for the Amhara area, create a slope map (in percent).*
2. **Potatoes are suitable for planting in areas where the slope is less than 20%. Create a suitability map for the slope.*

8.2.4.3 **Raster calculator*

The “Raster Calculator” provides you a powerful tool for performing multiple tasks that you have seen in math algebra in one unique interface. You can perform mathematical calculations using operators and

functions, adset up selection queries. Inputs can be raster datasets or raster layers, coverages, shapefiles, tables, constants, and numbers.

In order to find the rater calculator you need to activate the spatial analyst menu bar, by right clicking on the menu.



The raster calculator allows you to combine different rasters with math algebra, as for example adding up rasters, multiplying raster, etc. But it also includes the functions you have seen under predefined functions.

Use the raster calculator to program you computation. The functions discussed in predefined function can be introduced by typing them. For example the slope can be computed as follows : slope[put here the digital elevation map].

*Exercise 8-9

1. *You have created a potatoes suitability map in terms of elevation, slope and soil. Combine the three into a potatoes suitability map (hint use raster calculator). What are the mathematical rules that you could use for the aggregation? Which one would you choose?*
2. *Perform different aggregation techniques and compare the outcome.*
3. *What is your opinion about the suitability map that you have created? Are there other variable which should be included to determine the suitability for potatoes?*
4. *Create your own model for the suitability of potatoes, search for any data you are missing (on the CD, or in exercise folder, or on the internet), and perform your own*

8.3 *Interpolation

Often some data is available at certain point locations, for example meteorological data from weather stations or soil samples. However, for modeling purpose one might need to have a full coverage map giving an indication of data at locations where they have not been sampled. The process of transforming point based data into a full coverage grid map is called interpolation.

All interpolation techniques estimate the unsampled location (any grid cell) by averaging the values from sampled points for which data is available. Technically, for each grid cell in the area, an interpolation rule defines which sampled point has to be considered and weighted to compute an average. Different interpolation techniques exist and they differ by the way in which they average the sampled data over geographical space.

The most common interpolation techniques are inverse distance weighting, kriging, natural neighbor, spline and trend. All these interpolation techniques can be found in the ArcGIS Toolbox:

Spatial analyst tool → interpolation

Explaining the different interpolation techniques goes beyond the scope of this training course. The ArcGIS helpfile explains the difference between the techniques in detail. For this course, we will focus on the inverse distance weighting (IDW) technique only.

For IDW, the average is computed by attributing each sampled point a weight that depends on the distance to the grid cell which is to be estimated. This implies that sampled points that are nearer to the grid cell in consideration are more important than the sampled points that are further away. Mathematically, the estimated point is given by:

$$Z = \frac{\sum_i \omega_i Z_i}{\sum_i \omega_i},$$

where Z is estimated value for one given grid cell (and this computation is done for each grid cell), Z_i is the sampled point at a distance d_i from Z, and w_i is the inverse distance weight factor. There are various ways of defining w_i however, the inverse square of distance is widely used which can be written as,

$$\omega_i = \frac{1}{{d_i}^2}.$$

* Exercise 8-10

1. **Load the shapefile you have made from the "RR.txt" file in a previous exercise. Interpolate this data by using inverse distance weighting.*
2. **What does the new map tell you?*
3. **How would you use this map for a suitability analysis? Perform this step and add the result to the suitability analysis run in the raster data chapter.*

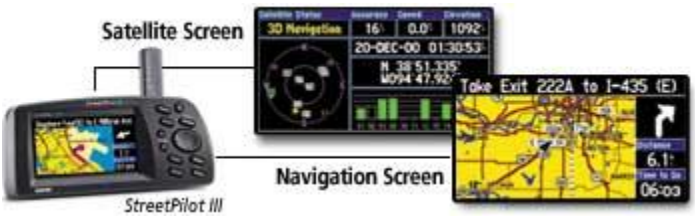
9 Working with a GPS

9.1 *What is a GPS?*

The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed into orbit by the U.S. Department of Defense. GPS was originally intended for military applications, but in the 1980s, the government made the system available for civilian use. GPS works in any weather conditions, anywhere in the world, 24 hours a day. There are no subscription fees or setup charges to use GPS. Garmin is the name of the market leader for GPS receiver.

9.2 *How it works*

GPS satellites circle the earth twice a day in a very precise orbit and transmit signal information to earth. GPS receivers take this information and use triangulation to calculate the user's exact location. Essentially, the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is. When combine with distance measurements from a few more satellites, the receiver can determine the user's position and display it on the unit's electronic map.



A GPS receiver must be locked onto the signal of at least three satellites to calculate a 2D position (latitude and longitude) and to track movement. With four or more satellites in view, the receiver can determine the user's 3D position (latitude, longitude and altitude). Once the user's position has been determined, the GPS unit can calculate other information, such as speed, bearing, track, trip distance, distance to destination, sunrise and sunset time and more.

9.3 *How accurate is GPS?*

Today's GPS receivers are extremely accurate, thanks to their parallel multi-channel design. Garmin's 12 parallel channel receivers are quick to lock onto satellites when first turned on and they maintain strong locks, even in dense foliage or urban settings with tall buildings. Certain atmospheric factors and other sources of error can affect the accuracy of GPS receivers. Garmin® GPS receivers are accurate to within 15 meters on average.

9.4 *The GPS satellite system*

The 24 satellites that make up the GPS space segment are orbiting the earth aproximately 12,000 miles above us. They are constantly moving, making two complete orbits in less than 24 hours. These satellites are travelling at speeds of roughly 7,000 miles an hour.

GPS satellites are powered by solar energy. They have backup batteries onboard to keep them running in the event of a solar eclipse, when there is no solar power. Small rocket boosters on each satellite keep them flying in the correct path.

9.5 *What is the signal?*

GPS satellites transmit two low power radio signals, designated L1 and L2. Civilian GPS uses the L1 frequency of 1575.42 MHz in the UHF band. The signals travel by line of sight, meaning they will pass through clouds, glass and plastic but will not go through most solid objects such as buildings or mountains.

A GPS signal contains three different bits of information - a pseudorandom code, ephemeris data and almanac data. The pseudorandom code is simply an I.D. code that identifies which satellite is transmitting information.

Ephemeris data, which is constantly transmitted by each satellite, contains important information about the status of the satellite (healthy or unhealthy), current date and time. This part of the signal is essential for determining a position.

The almanac data tells the GPS receiver where each GPS satellite should be at any time throughout the day. Each satellite transmits almanac data showing the orbital information for that satellite and for every other satellite in the system.

9.6 *Sources of GPS signal errors*

Factors that can degrade the GPS signal and thus affect accuracy include the following:

- Ionosphere and troposphere delays - The satellite signal slows as it passes through the atmosphere. The GPS system uses a built-in model that calculates an average amount of delay to partially correct for this type of error.
- Signal multipath - This occurs when the GPS signal is reflected off objects such as tall buildings or large rock surfaces before it reaches the receiver. This increases the travel time of the signal, thereby causing errors.

- Receiver clock errors - A receiver's built-in clock is not as accurate as the atomic clocks onboard the GPS satellites. Therefore, it may have very slight timing errors.
- Orbital errors - Also known as ephemeris errors, these are inaccuracies of the satellite's reported location.
- Number of satellites visible - The more satellites a GPS receiver can "see," the better the accuracy. Buildings, terrain, electronic interference, or sometimes even dense foliage can block signal reception, causing position errors or possibly no position reading at all. GPS units typically will not work indoors, underwater or underground.
- Satellite geometry/shading - This refers to the relative position of the satellites at any given time. Ideal satellite geometry exists when the satellites are located at wide angles relative to each other. Poor geometry results when the satellites are located in a line or in a tight grouping.
- Intentional degradation of the satellite signal - Selective Availability (SA) is an intentional degradation of the signal once imposed by the U.S. Department of Defense. SA was intended to prevent military adversaries from using the highly accurate GPS signals. The government turned off SA in May 2000, which significantly improved the accuracy of civilian GPS receivers.

9.7 *Different GPS receivers*

Many different GPS exist from different manufacturers. Every GPS comes with its own user manual, which should be studied before use.

Garmin is the market leader for GPS, and has various different types of models with different features. The Garmin Etrex model is developed for outdoor sport and is the easiest to use for georeferencing in rural areas.

Different models exist within each type of GPS. The most basic GPS have a compass and allow you to save waypoints, i.e. points of interest, as well as tracks, i.e. routes one has travelled and recorded with the GPS. More expensive models have a USB connection allowing download of the data directly to a computer. These models also have an altimeter that needs to be calibrated. Note that the altimeter of a GPS is always relatively inaccurate.

9.8 *Collecting data with your own gps*

As every GPS is different it is not possible to provide a step by step procedure in this manual. This manual discusses only the steps that should be considered when using any particular GPS rather than how to perform them. In a separate document the quick reference guide is provided, as well as the full user manual of the Garmin Etrex Vista HCx, the GPS used during this training course. If you have another type of GPS, then the steps presented in this manual are still relevant to you, but the use of your GPS might be different and you need to consult the user manual.

First steps for using a GPS are to put the batteries into the GPS, and turn it on. Use the user manual to familiarize yourself with your GPS, and to find the main menu and view the options offered to you.

9.9 *Setting up a GPS*

Once you have to switch on your GPS you need to check if the settings are correct. For the Etrex Vista HCx you need to go the setup menu and the select the following features:

Feature	Parameters to check	Explanation
Unit	Position format : hddd.ddddd or hdd mm'ss.s or hddd mm.mmm Map datum : WGS 84 Distance : metric Elevation : meters Depth : meter	It does not matter which position format you use, you can always change it to another format later on Note that with these settings are in correspond to a geographic coordinate system (see chapter 6 on projections)
Time	Put the right time zone : Cairo	
Calibration	Compass Altimeter	Turn slowly the GPS You need to know the altitude of the point at which you are calibrating
System setup	GPS : on Battery type : put the battery type you use NiMH is rechargeable , Alkaline is normal WAAS : enable	Received info from satellite Is the most accurate measurement method

9.10 *Waypoints and position format*

Waypoints are the points on the ground which you want to georeference (record their location). If you are at the location you want to georeference you need to mark this point. Look at your user manual under "marking a waypoint".

Some of the GPS units allow you to give a specific name to the point. If it doesn't note down the point number in your field notebook as well as the name of the location or the object you are georeferencing.

Note that the coordinate of each point will be saved in the position format you have selected in the setting. Three different formats can be distinguished:

1. Coordinate containing degrees (integer), minutes (integer), and seconds (integer, or real number) (DMS).
2. Coordinate containing degrees (integer) and minutes (real number) (MinDec).
3. Coordinate containing only degrees (real number) (DegDec)

It does not really matter which format you choose, as you can always convert coordinates from each format to the other. But if you transfer your coordinates to the computer manually it is the easiest to capture your data in decimal degrees (DegDec) so that you do not need to convert them further.

9.11 *Tracking*

Tracking is a method that records a point every minute (or at a user specified time interval or distance) thus recording where you have travelled. Note that for tracking, the GPS needs to be switched on all the time. Tracking is not automatic, so you need to need to go the track menu, and switch the “track log” on.

You can use tracking if, for example, want to measure an area, such as a field. You have to walk around the area you want to measure with tracking switched on. Some GPS allow you to calculate directly the area. If not you can calculate the area in ArcGIS once you have exported the tracking route.

9.12 *Downloading your data to a computer*

9.12.1 Manual method

Use an excel file with 3 columns X, Y and Name. Type the western coordinate into X and northern into Y as well as the name of the location into the last column. Note that the easiest way is to use hddd.ddddd position format (decimal degree format). If you have used another format you need to convert it into decimal degrees. If you have the coordinates in another format use the following conversion rule to get decimal degree format coordinates.

Conversion from DMS to Decimal Degree

Given a DMS (Degrees, Minutes, Seconds) coordinate such as W 87°43 41, it's trivial to convert it to a decimal degree using the following method:

- Calculate the total number of seconds, 43 41 = (43*60 + 41) = 2621 seconds.
- The fractional part is total number of seconds divided by 3600. 2621 / 3600 = ~0.728056
- Add fractional degrees to whole degrees to produce the final result: 87 + 0.728056 = 87.728056
- Since it is a West longitude coordinate, negate the result.
- The final result is -87.728056.

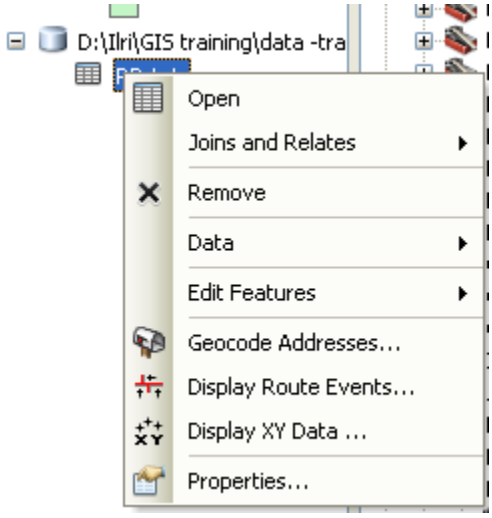
Conversion from DMDM to Decimal Degree

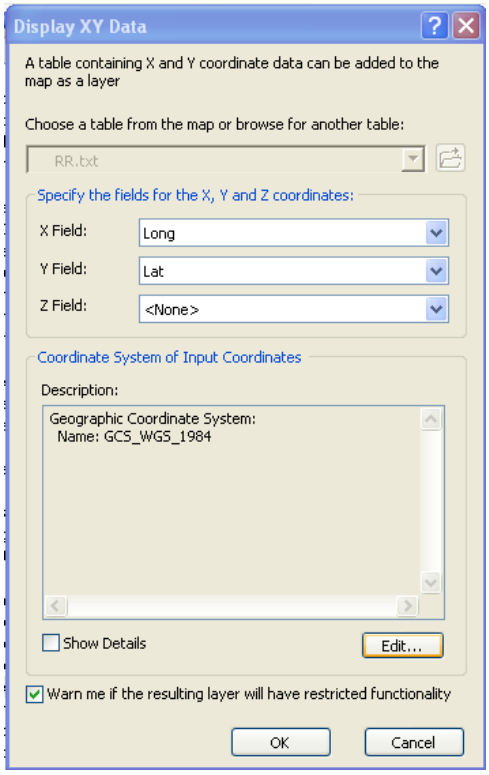
Given a coordinate in DMDM (Degrees, Minutes, Decimal Minutes) such as 40°26.7717N, 79°56.93172W, it is trivial to convert it to a decimal degrees using the following method (for example for 79°56.93172W):

- The integer number of degrees is the same (79)
- The decimal degrees is the decimal minutes / 60 (56.93172/60 = 0.948862)
- Add the two together (79 + 0.948862 = 79.948862)
- Negate the value if it is South or West (in this case, West, so -79.948862)

Once your excel file is ready, you can load it into the ARCgis, with the “add data” button:

Select the excel file in which the coordinates are saved, and a table will appear in your list of layers. Right click on the table and select “Display X Y Data”, select your X column as X and Y column as Y.





Check if you have the correct projection. If not, set the projection by pressing the “Edit” button and follow the same procedure as presented in the projection chapter. The output will be an event layer. If you right click on this event layer and select export data, you are able to save your points as a shapefile.

Exercise 9-1

1. *In a new project, load the RR.txt file.*
2. *Project these points and save them as shapefile.*
3. *What is the correct coordinate system for this shapefile*
4. *What does type of information is given by the RR shapefile? Make an informative map with this data.*

9.12.2 Downloading coordinates with a USB cable

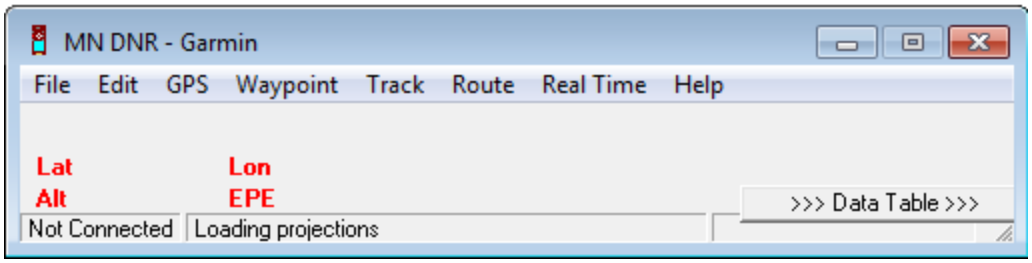
If your GPS can be connected to your computer with a USB cable you can download the coordinates. This is a much safer (no copying errors) and faster way. However your computer must be able to recognize and download the data. You need to insure that your computer has:

1. The driver of your GPS installed. A driver is a program that enables your computer to recognize the GPS. Every GPS with USB connection comes with a driver CD. But you can also always download the driver from the producers' website for free. For Garmin, you can find the driver under : http://www8.garmin.com/support/download_details.jsp?id=591
2. A program to download the coordinates. There are many programs to do this. If you buy a Garmin product, it will be delivered with the MapSource program that allows you to download and upload data to your GPS. This program is not available for free.
   Without access to MapSource, the easiest program to use to download data is the DNRGarmin program. This software is produced by the University of Minnesota and is available for free. You can download it from http://www.technoleros.com/dnrgarmin-gps-541/. This software only recognizes Garmin products.

Once your computer is ready for data transfer with the driver and the download program installed, you need switch the GPS into **sending mode**. On the Garmin Etrex Vista HCx, in the main menu you select "setup" and "interface" and switch it to "connected". Now you can connect your GPS to the computer with the USB cable and use the download program you have installed.

9.12.3 Downloading your data with DRNGarmin

Check if your GPS is connected, recognized by your computer and in sending mode. Open DNRgarmin program and you will see the following window with the file, edit, GPS, Waypoint, Track, Route, Real time and Help menu.

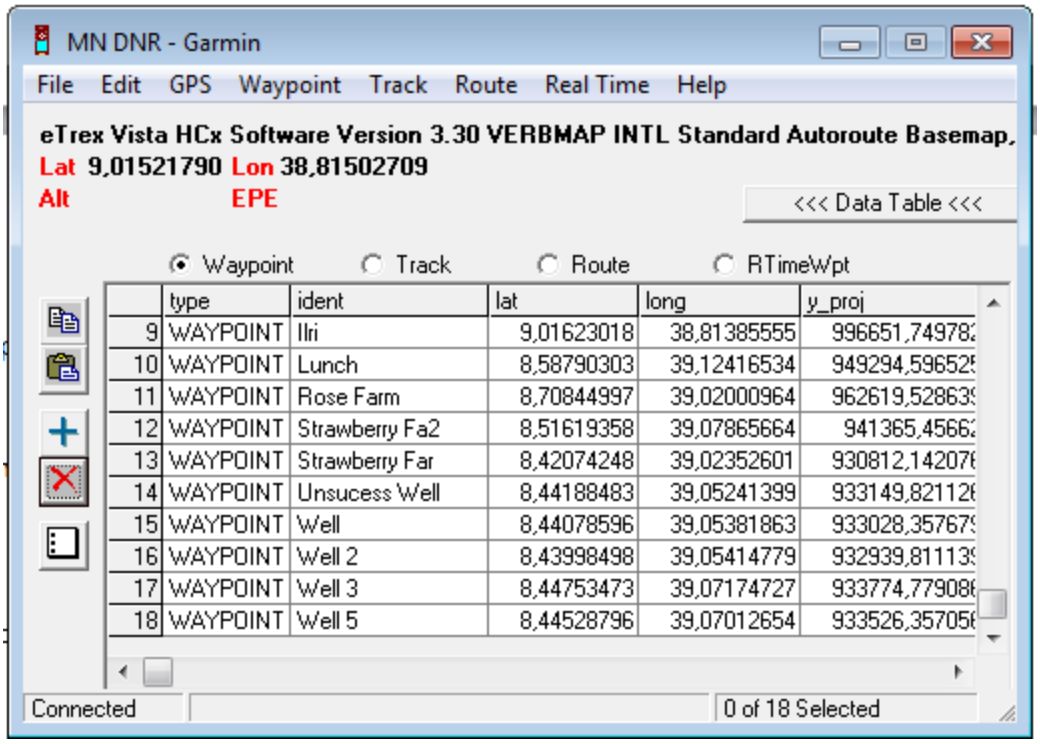


In order to download your data you have to follow these steps:

- Set the right port
    - Go to the GPS menu
    - Set port to USB
- Open port
    - Go to GPS menu
    - Open port
- Check/set the projection the projection

  (if you have set your gps right, your data is in a geographic coordinate system WGS, you can use this directly in ArcGIS. DNRGarmin also allows you toproject your data without ArcGIS, therefore you need to set your projection)
    - Go to file menu
    - Select “set projection”
    - Check if you have the right projection or change it to WGS 84 UTM 37N
- Download waypoint
    - Go to menu waypoints
    - Download

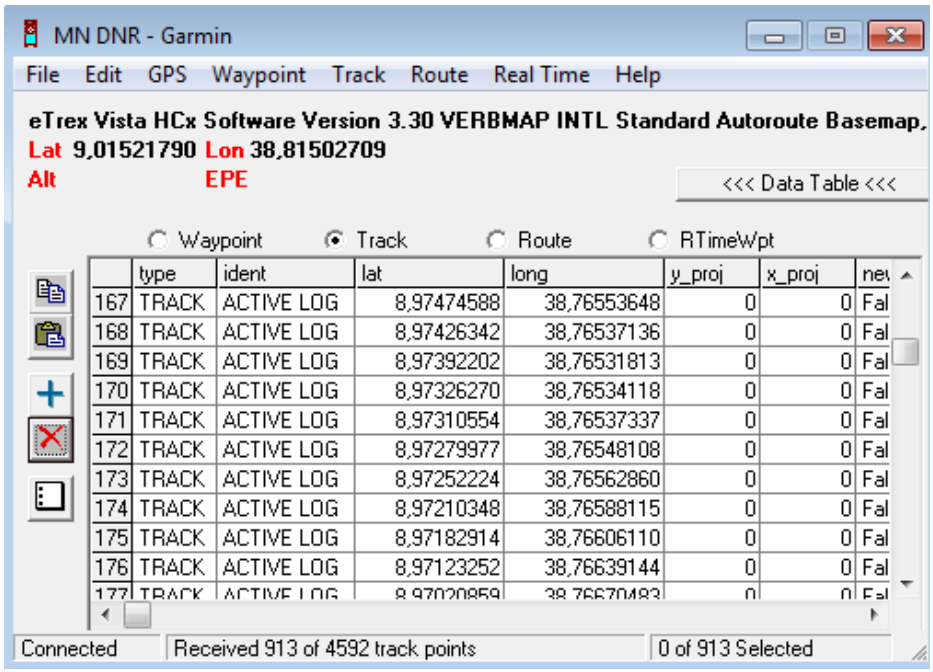
      Then you will see the table below:



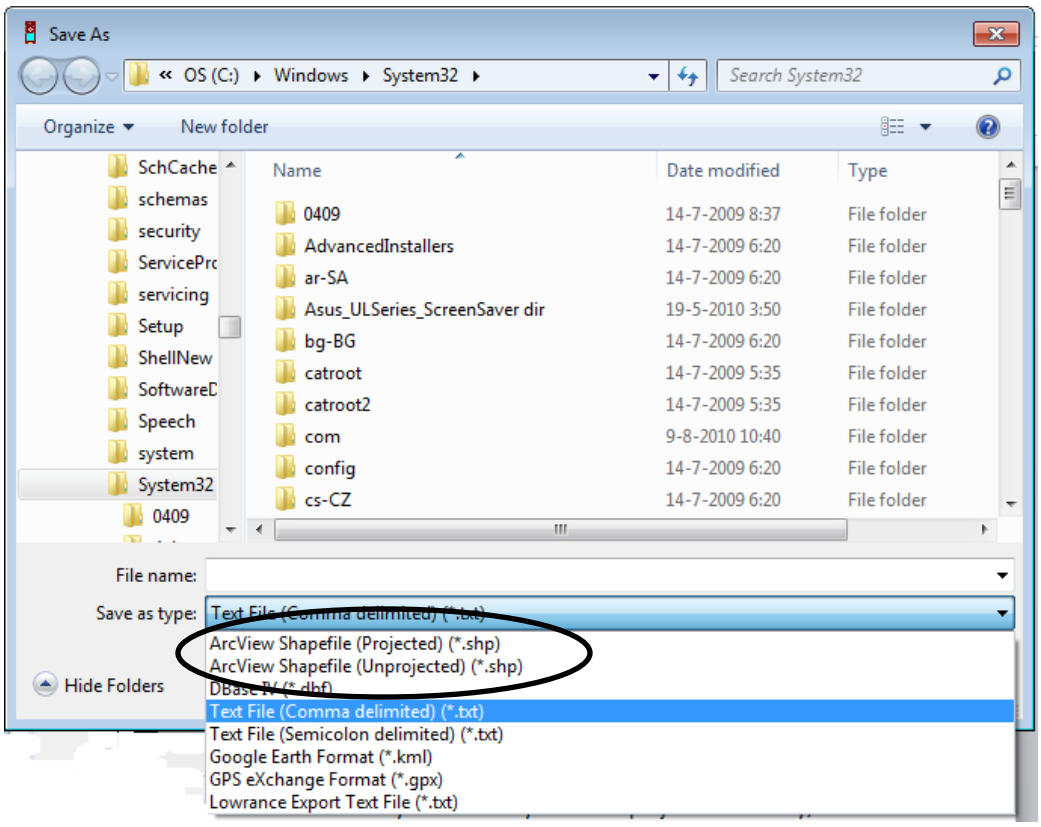
- You will see a table with the coordinates and with the name you have given to each point. Also note the button, waypoints, track, routes and RtimeWpt, which allow you to switch between different data you have collected.

- Do same with your track
  - Go to track menu
  - Select download

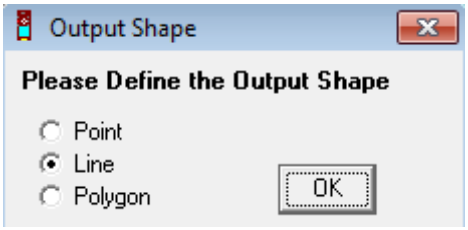
  You will see the track information as in the table below:



- If DNR garmin does not automatically project your data (if y_proj, x_proj = 0 at the end of the downloading process), then do this manually. Note that if you set the projection correctly, this is done automatically
    - Go to menu edit
    - Project coordinates
- Now save your data on the computer
    - Click on waypoints so that you see the table with waypoint
    - Go to menu file
    - Save as “projected shapefile” if you projected your data, or as “unprojected shapefile” if you did not project the data



- Do the same but first click track
  - Same procedure than before
  - Save the track as a line



Now you have successfully downloaded your own data and can easily load it to ARCgis, or to any other GIS software that support shapefile.

Exercise 9-2

1. *Download the track and waypoints from your field trip.*
2. *Map the points and the tracks.*
3. *What are the coordinates of the points of interests that you have visited?*
4. *What is the distance from starting point of the field trip to the points of interests?*
5. *What is the area of one of the points of interests?*
6. *Add metadata to the data you have collected during field trip.*

10 *Vector Data entry and editing

In Arc GIS it is possible to edit or create a new vector dataset. In this exercise you are going to learn how spatial and attribute data is stored in a GIS. You will then practice entering spatial and attribute data into a GIS.

An efficient way to work on the data entry or editing of shapefiles is to uses “geodatabase”. There are two types of Geodatabases, the Personal Geodatabase and the large (ArcSDE) Geodatabase. Personal Geodatabase stores data in MS Access database. The large Geodatabase stores data in a separate Oracle, SQL server, Informix or DB2 database that is connected to ArcGIS via ArcSDE (spatial data engine).

10.1 *Data entry and management*

Data entry and management are tasks that complement all GIS work. Data has to be entered and stored in a proper digital format (in the computer) to undertake any GIS analysis. Different methods are used for data input. Data can be recorded directly from the field in a digital format by using devices as Global Positioning Systems (GPS) and Satellite Imagery. Data also can be input from analogue format (hard copy) by means of digitizing or scanning. Spatial data and their attributed data are stored in the computer in different ways depending on the GIS software in which they were created. However most commonly the data are arranged in the form of tables.

10.1.1 *Working with geodatabase

Geodatabase is symbolised as a barrel  icon.

The‘‘Geodatabase” concept can be simply explained as a container (database) that stores data. A geodatabase contains feature classes. Feature classes are collections of geographic features that share the same geometry types (point, line or polygon), attributes and spatial references. Physically feature class information is stored in a collection of tables inside the database.

10.1.1.1 *Explore personal geodatabase*

To explore an existing personal geodatabase:

- Connect to the folder where the data is stored.
- Expand the folder to see the geodatabase. (By clicking on the small + icon next to the folder icon.
- Click on the feature class you want to view
- Click on the preview tab to see the spatial representation of the feature class (i.e Geography bar).
- View the table that stores feature class information (i.e Table bar)

When you view the table that stores the feature class information, the spatial representation of the feature class (X,Y coordinates that represent the polygon, line or point geometry) is stored in the “shape” field.

Each geometry feature is represented by a row or a record in the table. Other attribute information (i.e. ID, Area, length etc) is stored in additional fields.

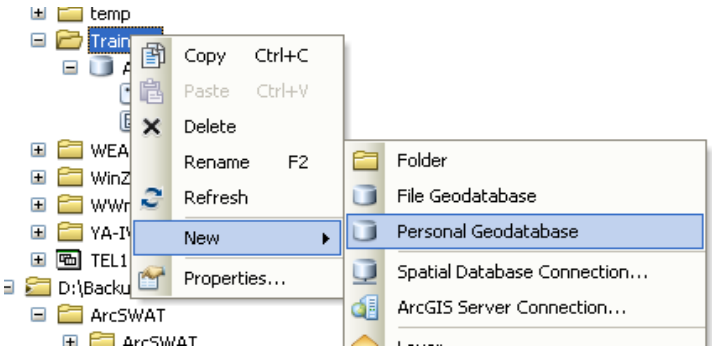
* Exercise 10-1

1. **Explore the personal geodatabase 'ARARI'*
2. **How many feature classes are inside the database?*
3. **Preview the feature class 'woredas'*
4. **What is the geometry type of this feature class?*

10.1.1.2 **Creating personal geodatabase and feature classes*

To create personal geodatabase:

Arc Catalog → right click on a folder → new Personal geodatabase



To create a feature class:

- Right click on the geodatabase → new feature class
- Name the feature class
- Skip the next window by clicking next
- In the new window assign the shape type (point, line, or polygon) and the spatial reference of the new feature class.
- Click on the 'Shape' field → In the field properties 'polygon' is assigned to the geometry type as default. Click on 'polygon' a dropdown menu will appear. Choose the geometry type you want.
- In the field properties assign the spatial reference you want
- Click finish

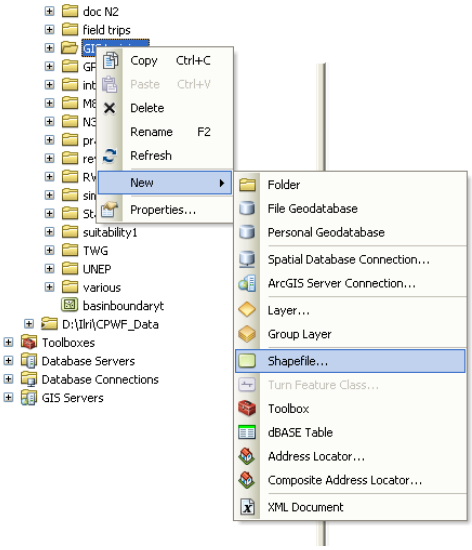
* Exercise 10-2

1. **Create a new geodatabase*
2. **Create a new feature class with' point' geometry type*
3. **Set the spatial reference of the feature class to UTM Zone 37*
4. **What is the advantage of working with a personal geodatabase?*

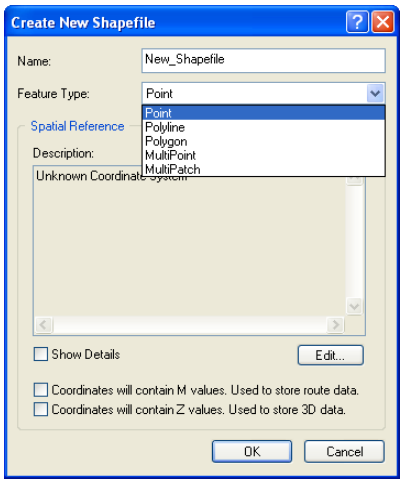
10.1.2 *Working with shapefiles

The three (3) basic types of vector data are point, polyline and polygon, all of which consist of nodes. The most common vector datafile is a shapefile and only one type of data can be saved in each shapefile.

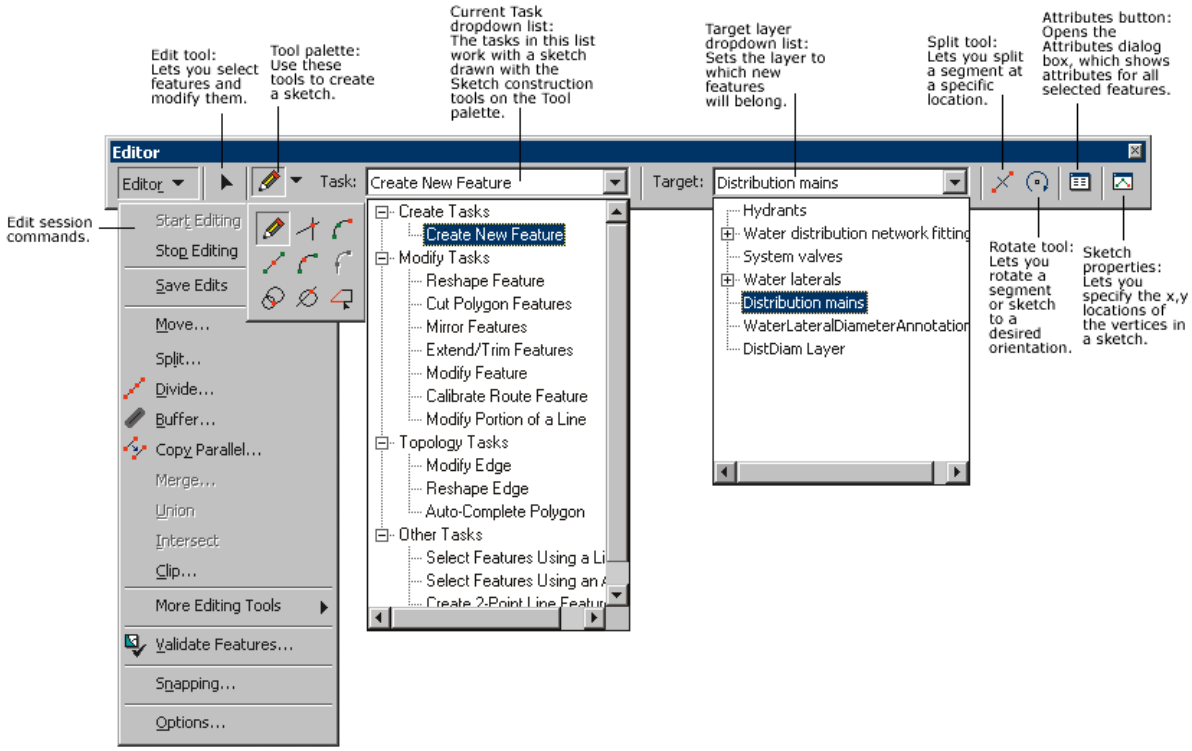
To create a new shapefile go to Arc Catalog → right click on a folder → new shapefile



You need to indicate which type of feature you want to create (point, line, polygone) as well as the coordinate system you work in.



10.2 *The editor toolbar



The editor tool bar allows you to edit your existing shapefile or create an empty new shapefile. Under "Task" you can choose the tasks you wish to perform. We will only look at creating new features and modifying features.

The "Target" indicates the layer which will be edited. If you target a point file then you will edit points, if you target a polyline file than you will edit lines and if you target a polygon you will edit polygons. You cannot mix the different type of features. For example, you cannot create a point on a polyline shapefile, you will need to create a new shapefile for the points.

10.2.1 *Point Data Editing

Editing points is one of the simplest editing tasks and includes moving, deleting and adding points. As a first step, similarly to attribute table editing, you need to start an editing session. Activate the editing menu bar → editor → start editing.

For modifying existing points, Select the “Reshape Feature” option and indicate which shapefile you want to modify. You can use the selection tool to select the points you want to modify.

Note that you can use the magnifier window to zoom into the location you are working on. If you want to move existing points or delete existing point use the reshape feature, select the point, move it or delete it with the delete icon 

If you choose the task “Create New Feature” the Sketch Tool will become available  .
Click the locations on map to which you wish to add a new point. After adding a new point, click the Attributes icon on the Editor toolbar  . The Attributes window will appear where you can add the attributes that belong to the point you are creating.

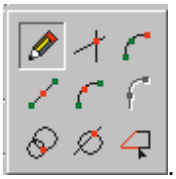
* Exercise 10-3

This exercise shows you how to digitize maps, and only can be done if you have completed the georeferencing exercises.

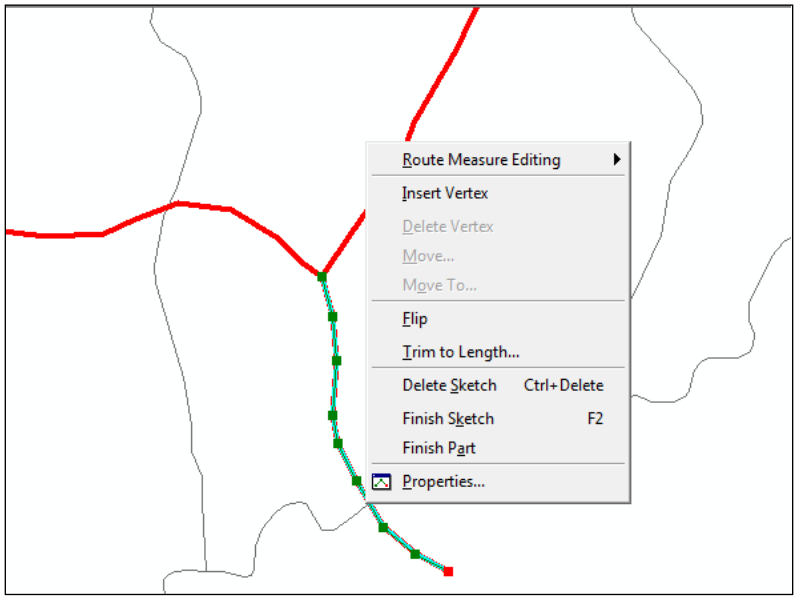
1. **Load the geo-referenced image of Ethiopia (produced in the exercise on georeferencing)*
2. **Create a new shapefile for points and save it as “mytowns”*
3. **In this new shapefile create a point for Addis Ababa and for Bahir Dar*
4. **Create a point for the town you are living in*
5. **Edit the attribute table, indicating the name of the location as well as your relation to this location.*
6. ** create the metadata for the “mytowns” shapefile*

10.2.2 *Editing Line Data

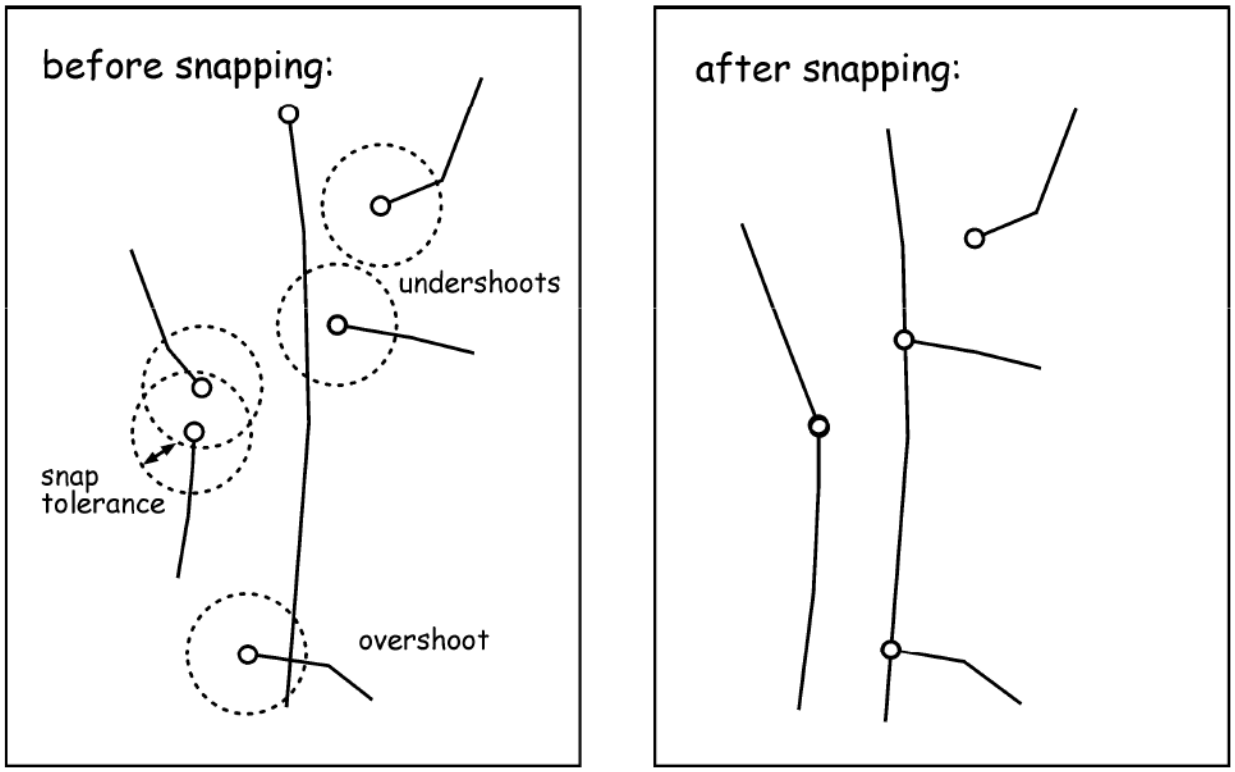
Editing line data is very similar to point data except that there are more tools available. You can select a line and slit it by using the “Splitting Tool”  or rotate the feature by using the “Rotation Tool” 

You can create a New Line with the Sketch Tool. You can choose the most appropriate tool for designing the types of line you want to design from the sketch tool  .

You can also working with nodes (vertex. These are points that subdivide your features. In order to work with nodes you should switch to the task “Modify Feature”. This mode allows you to see the nodes. By right clicking on the feature you can modify, delete and add nodes.



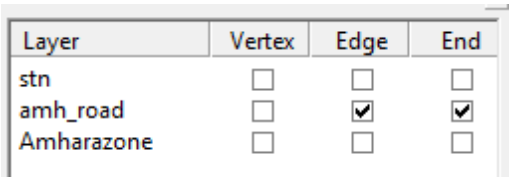
“Snapping” is a tool that can help establish exact locations in relation to other features. The snapping environment makes this type of task accurate and easy to use as shown in the figure below.



The snapping environment can also be used to move a feature to a precise location in relation to another feature. For example, you can move a parcel and have one of its corners jump, or snap, precisely to a corner of another parcel. Simply move the parcel's selection anchor to its corner vertex after setting the appropriate snapping properties. Then move the parcel toward its new location until the selection anchor snaps to the corner vertex of the other parcel.

Setting the snapping environment involves setting a snapping tolerance, snapping properties, and a snapping priority. The snapping tolerance is set on the General tab of the Editing Options dialog box (Editor menu > Options), while snapping properties and priority are set on the Snapping Environment dialog box (Editor menu > Snapping).

In the Snapping box you need to indicate which are the elements to be used for linking the features: the vertex, the edge or the end.



*Exercise 10-4

1. *Load the road map; delete the road between Bahir Dar and Gonder
2. *Load the geo-referenced topographic map (Woreta sheet) from the geo-referencing exercise. Digitalize the churches around Hamusit Mender.
3. *Digitize the road that passes through Hamusit Mender
4. *Digitize Hamusit Mender town.
5. *Edit the attribute table for each feature you have created.
6. *Create the metadata for each file